Master Thesis

Inventor mobility in the pharmaceutical industry, 2001-2012

Arnout Jol

Student number: 325301

Supervised by: Dr. Ajay Bhaskarabhatla

Co-reader: Dr. Bas Karreman

Abstract

Newly released patent application data by the US Patent Office allows this paper to analyze inventor movement using a more accurate proxy than previously available. Previous literature has focused on mobility effects in the United States, this paper aims to fill a gap by concentrating on some European mobility questions, using the changed economic circumstances caused by the financial downturn after 2008 to create a before and after scenario. Geographical and firm data from applicants with multiple patent applications is exploited to estimate three models, namely mobility of inventors across countries, cities and firms. The models are used to estimate the effect of being European, being Southern European, being English-speaking, being a big European firm and being a big European city on mobility of inventors. This paper finds mixed support for its hypotheses that European or Southern European nations see a larger downturn in mobility than other nations after the financial downturn and that city size has an influence on mobility. No effect of firm size is found. This paper also finds that English speaking nations attract less inventors than other nations and that there was a global downturn of inventor mobility after the financial crisis.

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Introduction

Migration has a big impact on individuals and countries alike. Television news and newspapers report of changes and proposed changes in immigration law nearly every day. However, immigration in popular culture is a very different issue than migration of highly skilled individuals who can have a real and quick effect on economic prospects of countries, cities and companies. Economic literature concerning migration of high-skilled individuals often focuses on US patterns, due to the size of the economy and the singularity of the data. There are a number of ways in which these papers discuss migration, relying on either data of the US government on immigration or on data of diversity of nationality in US companies.

This paper will try to divert from this focus on the US patterns by exploiting a newly released dataset. The US Patent Office, in cooperation with internet giant Google, released a dataset consisting of every patent application between 2000 and 2012. Compared to data previously available that only comprised patent grants, this dataset paints a more thorough picture of patterns in research and development (R&D) and more importantly, is much denser in its representation of inventor patterns than the more spotty patent grant data. Another advantage of using patent application data is the more timely nature of application data: patents can be granted years after the application by the inventor, meaning extracting information about the inventor based on grants is by nature highly inaccurate in time scale. The density of applications per inventor allows a more detailed look at mobility patterns of inventors, due to the increased number of applications close together in time.

Instead of a comprehensive review of the entire dataset, this paper chooses to single out patent applications in the pharmaceutical industry. While this is limiting the scope of the paper, it increases accuracy. The reasons to choose for the pharmaceutical industry specifically are twofold. Firstly, it is an industry that relies on formal R&D more than most industries, as illustrated by the fact that by far the most patent applications in the dataset originate from the pharmaceutical industry. Any analysis done on the pharmaceutical industry will carry more weight and has more relevance than analysis for most other industry, due to the larger importance of R&D for the well-being of the company. Secondly, more than most industries, the pharmaceutical industry is dominated by large multinationals. Thus, movements of inventors are expected to have a bigger impact than in an industry where job-hopping between small companies and start-ups is a more natural and unavoidable process. Moreover, while the data is comprehensive, it is far from error-free. It is outside of the scope of the paper to manually and automatically fix errors in company names (by far the most error-prone) and inventor names. The domination of large industries in the pharmaceutical industry provides a dataset that is more straightforward to control for errors. Moreover, mobility of inventors because of bankruptcy instead of business opportunities, which would be less telling of business patterns and more of volatility, is less likely to occur in an industry where most employees are employed by stable and large companies.

By analyzing the mobility patterns of the pharmaceutical industry during the extraordinary time period of the first part of the 21st century, this paper will be able to contribute to existing literature by providing clarity on mobility patterns in the EU, a scientifically very underrepresented, but economically highly relevant part of the world. It will do so by first contextualizing mobility patterns of Europe in a world framework, then focusing on inter-European patterns. It will split Europe into a Northern, less affected, part and a Southern, more affected, part. By using the extraordinary financial downturn of 2008 and following years, it is possible to construct a before and after area, and with the split of North and South a crude treated and untreated group, with which economic and societal can be tested on different groups of the same industry. Doing so will yield information about behavior of both companies and inventors alike and give insight in business strategies and patterns.

The paper will start with discussing existing literature on mobility, business strategies under pressure and in this will point out the lack of literature on European countries. It will proceed by hypothesizing the influence of multiple variables on mobility, where mobility will be defined by a movement across country, city or company. After discussing the data and methodology, a section will be devoted to analyzing the data, after which formal regression analysis will follow. This analysis will subsequently be discussed in light of previous economic literature.

Literature review

In this section, previous literature on the mechanics of inventor mobility and previous research on the trends and patterns of movements of the innovative sector of the pharmaceutical industry will be reviewed. Firstly, it is imperative to define the term mobility. Economic literature refers to mobility as well as to migration interchangeably, both words are indicators of the same mechanism as far as the intents and purposes of this paper are concerned. In the literature discussed in this paper, migration or mobility refers to the change of location (where location can be defined by different indicators) of an individual.

There are two ways to approach the phenomenon of the rate of mobility of inventors. Firstly, it is possible to focus on the decisions of individual inventors in order to determine factors that do or do not contribute to the propensity to move. This paper will not use this point of entry in the discussion, but it is useful to understand those small-scale decisions in order to find possible reasons for large-scale changes in mobility. Literature in the department of behavior economics as well as labor economics and general management and business studies are the main contributors on this side of the knowledge about mobility. After a short visit to the implementation of migration in classic economic literature, this paper will start off by reviewing mobility from the individual's perspective.

Many standard economic models use labor as a key variable. If labor increases or decreases, either productivity grows or declines, or alternatively the workforce grows or shrinks. If the latter is the explanation for an increase or decrease in the observed labor variable, it can be assumed that a part of the change can be attributed to labor migration. In a competitive world without restrictions, labor will flow from the country with low marginal product of labor to the country with high marginal product of labor until the two equalize, where the size of the marginal product depends on the characteristics of the country. Labor models are more specific and seek to explain the impact of mobility: Borjas (2000) uses a similar framework to the one described above, but focuses on the impact of an increase in the labor force in one country. He argues that an increase in labor will lead to lower wages for all laborers and an increase in output. Summarized, the standard economic models are useful tools in helping the understanding of economic principles, but barely shed light on the finer mechanisms of the mobility of inventors. The detailed aspects of the impact of inventor mobility, such as the networking effects the possible future loss of innovation are hard to model and are most likely not following a straightforward and linear pattern. Thus, it is more enlightening to study previous empirical work.

In a study for the Archimedes Foundation (co-financed by the European Commission), Rein Murakas et al (2007) conducted a study on individual decision making of researchers in Estonia. A representative sample of about 200 researchers, doctoral and post-doctoral students, half of them foreign, was interviewed on their decisions to stay in or move to the small Baltic nation of Estonia. A growing ex-USSR nation, Estonia is an interesting case of a nation with economic possibilities, but without being an "end-station" for the brightest inventors. The paper presents the decisions made by the researchers in the sample. Interestingly, legal procedures proved to be a bigger barrier for these researchers than country characteristics like language. Since this research is conducted among foreigners already located in Estonia, it is to be expected that they already accounted for linguistic and cultural differences and thus those concerns are underrepresented in the sample. Similarly, the biggest reason to move out of Estonia would be the quality of research institutions in the destination area.

A more general survey conducted among the same group type is the PatVal survey from 2003-2004 (Brusoni, 2006). discusses the results, noting that more than 75% of inventors in the sample did not move during a 10 year period. 15% of the patents produced are a result of a collaboration between individuals or groups of different companies. PatVal also asserts that spatial proximity is not a factor of influence in the development of patents. The only proximity type that positively influenced, according to these inventors, the development of patents is the organizational proximity (collaboration with inventors in the same organization). Brusoni elaborates on the survey and finds that large firms are more likely to patent inventions that are not used.

Most relevant literature on mobility is the analysis of large data in the field of innovation and mobility. The reviewed micro level analysis provides a background to the patterns observed in previous research and in the contribution this paper aims to make.

Over the past 20 years, the rate of mobility of inventors has steadily increased (Freeman, 2010). This pattern is similar when the rate of inventor mobility is compared to the rate of mobility of the rest of the population. There is a flow of inventors from what are unofficially called second world countries, notably China, India and former member countries of the USSR, to first world countries, notably Europe, the USA and Japan (Docqueir and Rapoport, 2012).

The unbalanced flow of inventors from one country to another is key in understanding both motives and consequences of inventor mobility. Why do inventors move from one country to another more than vice versa? What effect does this have? More attempts have been made to answer the second question than the first. A flow from one country to the other results in a brain-drain in the source country if the outgoing flow is not balanced by another incoming flow. To combat this, compensation schemes are designed by source countries, to capture part of the production of the inventor in the destination country (Kerr, 2008). Research focusing on the contribution of mobile innovators in the destination country tries to answer whether these inventors replace or complement inventors born in the destination country (Chellaraj et al, 2008).

These questions are difficult to answer without data, but recent wide availability of patent data has resulted in a number of studies into the effects of and the reasons for inventor mobility. Most of this research delves into inventors coming to the US. Thorough studies of inventor behavior in countries as economically advanced as the US, but smaller in size and grouped together like the nations forming Europe, are not as frequently studied. The most thorough analysis on inventor behavior is performed using OECD data (Widmaier and Dumont, 2011). This study finds that all European countries suffer from outward inventor mobility. At first glance, less well-off European countries suffer more from outward mobility: Poland is leading Europe in emigration rates. However, a rich country like the UK suffers from an above average emigration rate of 11%, possibly due to the lack of language barrier with the biggest economy and the largest recipient of inventor, the US. The OECD paper notes that of all member countries, the European countries take in the lowest amount of inventors. Complementary analysis indicates that adverse immigration policies are a possible reason for this low rate: European countries do not allow easier immigration for high-skilled applicants (Chaloff and Lemaitre, 2009).

An alternative way of examining the behavior of inventors is to analyze the country of birth of publishers of academic papers (Franzoni et al, 2012). Characteristically, academics are closely related to inventors, though the results discussed should be treated with caution. The paper uses dat from GlobSci and finds that Switzerland is home to the largest amount of foreign-born academics (57%) and the US in second place (38%). Larger European countries fall in the 15-30% foreign academics, with Italy as a negative outlier with only 3%. The most advanced Asian economy is also home to little foreign academics with 5% not being born or raised in Japan. Clearly, the second position of the US points to an open and competitive scientific job market, but it should also be cause of concern for European countries who, based on characteristics (smaller countries, many similar countries in the same region) could be expected to challenge or top the US in that position. The comparison worsens when intra-European mobility is ignored: the vast majority of mobility from emerging countries to advanced countries flows from China and India to the US (17% of academics in the US are Chinese, 12% are Indian).

A country with a positive inventor mobility rate either replaces (potential) domestic inventors with foreign inventors or complements its domestic talent with the foreign inflow to create a larger innovative sector than would be possible in autarky. As with any sociological debate, both viewpoints are supported by a number of publications. Some scientists argue that the influx of researchers in a destination nation crowds out domestic researchers (Borjas, 2009). He argues that enrollment rates of universities specializing in exact sciences have dropped in the US, with foreign students filling the spots.

Opposing views argue that this phenomenon is self-selective: only the brightest students enroll in these studies, thus the quality of students rises as the pool of students that apply for these positions is enlarged by including foreign students, from which the best are selected. A survey of about 2,000 inventors living in the US exhibits that foreign inventors rate the value of their invention higher than domestic invention on a technological and economic level (No and Walsh, 2010). This result is confirmed in a paper that finds that engineers not born but working in the US have a higher share than domestic engineers in the top-wage bracket (Hunt, 2013). This finding builds on his earlier work that proved that foreign-born patent applicants are more productive than native-born inventors (Hunt, 2009). A study that regresses the share of foreign inventors against the production as measured by number of patent finds that foreign patent applicants are more productive than domestic applicants (Chellaraj et al, 2008). A further subdivision is made, consisting of foreign graduate students. In turn, this group outshines the rest of the foreign inventors in productiveness and are more likely to be found in the technological sector.

Thus, there is ample literature on the effect of foreign inflow of innovative talent in the US. It remains difficult to give a defining answer to the question that was posed in the beginning of this discussion: do foreign inventors replace or complement US inventors? However, much of the evidence suggests that if foreign inventors replace domestic inventors, it is for the better as they appear to be the brightest and most productive inventors of the innovative sector. Thus, whether the foreign innovators replace or complement, the “cherry-picking” effect of selecting only the brightest talents is likely to have a positive impact on the innovative sector in the US.

Studies discussing the impact of inventor inflow in Europe are scarce. There is not one clear reason for the relative dearth of information on this phenomenon, but rather a number of contributing factors. Firstly, European nations differ from each other in many characteristics, including rule of law, language and strength of the national economies, meaning cross-country conclusions are hard to draw. Secondly, as has been described in this section, the inventor inflow in Europe is lower than in the US, thus analyzing the US is more relevant from a sociological point of view. Despite this, some studies have aimed to fill this gap in literature, as this paper will try to do too. One such study isolates high-skilled employment from general employment data in Germany, and finds a positive correlation between the ratio of foreign employees and patent productivity, as measured per German department (Niebuhr, 2010). A study conducted in the same year but focusing on London finds a similar, but small, positive effect, especially noting the increase in idea generation when management teams are diverse in background (Lee and Nathan, 2011). Another study confirms the benefits of cultural diversity in European nations, but is inconclusive on any effects on the patent productivity (Ozgen et al, 2012).

Evidence on the effect on the origin country of inventors and researched that moved away is even scarcer. Some small-scale efforts have been made, but research based on a comprehensive dataset are scarce and have only recently been attempted. The pioneering study uses patent data in conjunction with an ethnic name database to estimate the country of origin of non-native inventors (Kerr, 2007). The paper itself acknowledges the limitations of this approach, namely that no distinction is made between inventors born in the destination nation but with foreign names and genuine immigrants. Nevertheless, the results of the paper confirm the other findings discussed in this section. The number of immigrant inventors as a share of the total grew over the last decades and reached 30% in the 2000s, with Chinese and Indian immigrants making up the bulk of the influx. Kerr expands on this in 2008, when he examines the citations of patents produced by immigrant inventors and in summary examines whether these patents are cited more by innovators in the origin country of the author of that patent. He finds that there is a 50% increase in the number of citations stemming from inventors of the origin countries, which indicates that, limitations of the data taken into account, there is a bond between the inventor and his origin country. Thus, even if a brain drain may be a concern for a country, some of the brains that are leaving will still benefit the country. In light of this, it should perhaps be less of a surprise that countries such as China are so supportive of their students studying in other countries: in their knowledge accumulation, they are expected to benefit their country even if they do not return to it.

Kerr provides more literature on this subject in a paper that discusses the extent of investment of US multinationals in countries of origin of their innovative employees (Foley and Kerr, 2011). They find a positive relationship between the number of employees from a certain ethnicity and the amount of investment and innovation of the company in that country. This is more proof that country of origin of innovators does matter and that outward mobility can bring future benefits. This finding is confirmed by a study that regresses the impact of non-native inventors on the size of international cooperation in technology between the country of origin of the inventor and his current country of employment (Miguelez, 2013). A positive relation is found for all countries, further solidifying the idea that home country of mobile inventors is an important factor in research on mobility of inventors.

One previous paper specifically set out to investigate the phenomenon discussed in the previous paragraph, but for European countries (Breschi et al, 2013). Very different dynamics are at play here: mobility between nations bordering each other is much more common than in the US and, as elaborated upon in this section, immigration from China and India towards European nations is much less common. However, the paper finds that, similarly to the findings in the US, non-native inventors generally are above average earners in their sector.

However, in countries with little foreign inflow of talent, this effect is hard to measure. Moreover, as many European countries have close linguistic ties, the reliability of determining ethnicity based on name matching is questionable.

Previous literature has illustrated the importance of studying the mobility of inventors. However, it has not given insight in the causes for mobility. The clear trend from of inventors moving in the direction of rich countries is discussed in many of the studies, but more specific questions are often not addressed. One study that addresses the existence of personal reasons as possible cause for mobility, but decides to not address it due to difficulties in empirical measurement of such reasons (Saks and Wozniak, 2011). The same paper focuses on the business cycle as an influencing factor on the mobility of inventors: the rate of inventor mobility is pro-cyclical.

One factor that influences mobility is labor tax (Egger and Radulescu, 2009). The paper uses data from 49 countries in the year 2002 to establish that a higher personal income tax has a negative effect on the rate of inventor mobility. Moreover, a progressive tax rate, with high rates for high income brackets, is also negatively affecting the mobility of inventors. Another factor that has an impact on the mobility of inventors is the legal framework (Fallick et al, 2006). This paper uses the case of Silicon Valley, California to examine the effect of the possibility of free job changes, without legal implications. The paper shows that the rate of job changes is higher in the technological sectors in Silicon Valley are higher than elsewhere and attributes this to the legal possibilities, chief among which the lack of enforceability of non-compete agreements that employers can use elsewhere.

This paper aims to fill the gap in literature on possible causes of job mobility of inventors. The existing literature has tried to give partial answers to some reasons, but most of the research in the field has focused on the results of job mobility, without elaborating on why job mobility takes place and what factors influence it. Through selecting a specific industry, this paper aims to give some first answers to this question, building on the knowledge available on this phenomenon.

Hypotheses

This section will outline the hypotheses. The aim of the paper is to study inventor mobility in the selected pharmaceutical industry, specifically in the underrepresented European area. In the previous section, it was established that very little research is available on inventor mobility patterns in Europe, thus it is imperative to briefly contextualize the situation in Europe first, compared to the rest of the world. After that, the analysis will be concentrated on inter-Europe patterns. As touched upon in the introduction, the first decade of the 21st century is an ideal research opportunity due to the unnatural economic expansion and subsequent contraction and just as some of the most valuable economic research was only possible due to the Great Depression in the 1930s, this paper will try to capitalize on the economic swings that is expected to generate swings in behavior of a magnitude easier to capture with economic formal analysis. Multiple hypotheses will be stated, after which their inclusion in this paper will be justified.

Hypothesis 1.

English as primary language of country of application has a positive effect on the inward mobility of inventors

The high number of students from fast-growing nations, most notably China and India, is expected to cause an influx of inventor talent in countries where the primary language is English. The world's most renowned universities[1] and the largest multinationals are located in English-speaking countries and companies of these countries are expected to be the dream employers for many of the brightest inventors, both in terms of career opportunities and financial rewards. It is expected that English-speaking countries are more desirable destination locations for inventors originating from other parts of the world, thus will see an increase in inventor mobility compared to other countries due to the economic growth of countries such as China and India. The knowledge obtained from this hypothesis will

[1] 19 of the 20 highest ranked universities on the Times 2014-2015 university ranking are located in English-speaking areas. Full ranking accessible at: http://www.timeshighereducation.co.uk/world-university-rankings/2014-15/world-ranking (last accessed October 12, 2014).

contextualize the changes occurring in Europe, because most of the extra increase expected to be seen in English-speaking areas is an increase in immigration from outside of the Western world. Thus, excluding the English-speaking effect, the rate of mobility could be similar under similar circumstances.

Hypothesis 2.

Inventor mobility is negatively affected by the financial crisis of 2008

Inventors living in countries that were hit disproportionally in the financial crisis (with full impact in Europe starting in 2008) are expected to be more mobile after that date than inventors of other countries. In these countries, job security declines and opportunities in other countries are comparatively greater than in the home country, thus inventors are expected to have an increased incentive to move. The financial downturn allows a construction of a before and after scenario, in which severe economic events, with a different impact in different countries, can explain changes in inventor mobility.

Hypothesis 3.

Inventor mobility in Europe is more negatively affected than in the rest of the world due to the impact of the financial crisis

Building on hypothesis 2, hypothesis 3 focuses on the specific impact of the economic crisis in Europe. Archibugi et al (2013) found that European companies tightened budgets on innovation, preferring to retreat into their strongholds, with only opportunities for small and independent companies to benefit from the new playing field (and it should be kept in mind that small players in the pharmaceutical companies are less potent than in many other industries). That effect, in combination with the fact that European countries on average suffered a larger downturn than all the rich countries in the world according to data released by the Worldbank[2], fuels the expectation that Europe is more affected than the rest of the world and thus sees a larger decrease in economic activity and inventor mobility.

[2] http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG (last accessed October 1, 2014)

Hypothesis 4.

Inventor mobility is more negatively affected in Southern than in Northern Europe after 2008, due to the impact of the financial crisis.

Following the same line of thought as hypothesis 3, hypothesis 4 examines inter-European effects of the financial crisis more closely. The aforementioned Worldbank data on economic growth also solidifies the popular notion that Southern European nations suffered a bigger economic downturn than Northern European countries. In particular, France, Greece, Italy, Spain, Portugal and Ireland will comprise this group of so-called Southern European nations. Because of the extra impact of the financial downturn, it is expected that mobility of inventors will be similarly affected as for hypothesis 2 and 3.

Hypothesis 5.

Inventor mobility in Europe is more negatively affected by cities of large size after 2008, due to the impact of the financial crisis.

Referencing Archibugi et al (2013) once more, large companies are expected to retreat to their fortress positions, reducing risky diversions and focusing on their core business often located near or in historical economic hubs. Thus, mobility around large cities is expected to stabilize and slow down while smaller companies, according to this study, might seek to expand in unexpected places.

Hypothesis 6.

Inventor mobility in Europe is more negatively affected by firms of large size after 2008, due to the impact of the financial crisis.

Previous literature presents an ambiguous picture of the effect of firm size on the mobility of inventors. However, the most recently published papers, discussed in the literature review, generally find a negative effect and this paper expects a similar effect. The largest firms in the industry are expected to be more conservative in their hiring policies and can internally relocate inventors upon their wishes. Large firms are also assumed to be more economically stable, thus the necessity to change jobs due to macroeconomic reasons is smaller for employees of large firms.

Data

The main data source for this paper is the data released by the US Patent and Trademark Office (USPTO). Since approximately 2000, the US Patent Office registers not only granted patents, but every patent applied for by companies and individuals. This extensive database has recently been publicized with help of internet company Google. The dataset includes information on patent applicants, the name of their assignee (if applicable), the date of application and the application location. The US Patent Office categorizes patent applications in categories and subcategories, ranging from 2 to 996 (with not every number in use).

The dataset used in this paper ranges from January 2000 until January 2013. However, not all patent applications are promptly processed and at the time of data collection the database is missing applications for the last two years. The missing values can be assumed to be randomly distributed, thus these years of data can be used in the analysis, except for cases in which the inventor mobility rate is compared to, for example, the general mobility rate. When the last years of the dataset need to be cut from the analysis, it will be explicitly noted.

In the dataset, an entry does not necessarily represent a patent application. Each inventor name is uniquely entered in the database, thus cooperative patent applications appear more than once. For the purposes of the hypotheses, the number of patent applications per year is not relevant, but in the following chapters, a brief overview of the number of patent applications per year will be separately presented.

The dataset consists of 4,786,571 entries, divided in the aforementioned classes. Some classes feature only a handful of entries, some include tens of thousands values. It is not feasible to use the entire dataset, due to the necessity to manually error-check part of the dataset. As has been elaborated on in the introduction, this paper will study the case of inventor mobility in the pharmaceutical industry. Apart from the reasons outlined, the classes for this industry are the biggest in size. The US Patent Office categorizes class 424 as the main class and class 514 as the subclass for patent applications originating from this industry. Both classes are named “drug, bio-affecting and body treating compositions” and are divided into several subcategories (which will not be further defined and are not relevant to the purposes of this paper). Class 424 has 164,162 data entries and class 514 has 215,414 data entries (making it the largest class in the dataset), for a total of 379,576 data entries.

After automatic and manual error correction and standardization, full inventor names are assumed to be in the same format, starting with first name and ending with last name. The existence of individual errors remains a possibility, but is completely random. All entries with a unique inventor name will be eliminated as these do not exhibit any information about inventor mobility. After their elimination, 282,915 entries remain. These entries all have a non-unique full name and appear two or more times in the database.

In the brief general overview of trends in mobility, the full dataset including the unique entries will be used for a complete picture. This will be explicitly mentioned. The main source of economic data not included in the patent dataset is Eurostat and World Bank. From World Bank, a measure of economic openness is extracted as a control variable, henceforth denoted as *openness* in the regression result. This measure is imports and exports, together forming trade, as a percentage of GDP, per year. The inclusion of this control variable prevents extraordinary individual political or economic events to affect the rest of the results.

Methodology

This section will outline the methodology this paper uses to obtain the results of the empirical regressions.

The analysis is calculated by a series of logit regressions. Firstly, a dummy variable is created. Each inventor that changes location after the treatment date of 2006 and is the applicant of a pharmaceutical related patent is dummied. This allows a comparison between movers and non-movers before and after this date. The change is compared to the change in the treatment group. Equation (1) shows the construction of the dummy variable.

$$VarLead1 = Var(n+1) \tag{1}$$

Var takes the variable name of the variable that is analyzed for change following the critical year. In this case, the variables for the city of the inventor and the name of the inventor are forward lagged, for three years starting from the critical year. Using this forward lag, a variable is created that measures the amount of inventors that apply for patents from different locations than before. Three different models are constructed, using the variables country, city and firm.

$$Moved(x) = InvCityLead1 \& timedifference \leq (x) \tag{2}$$

In equation (2), a variable is created that measures the movement when the time difference is bigger than *x,* where *x* is set to one year in this analysis. This variable is the dependent variable in the difference in difference equation.

The independent variables of interest are the dummies created from treatment and control group. It is the coefficient of the variable that returns a one for treated after the critical date that is critical to the understanding of changes in the pharmaceutical industry. Formally, the difference in difference equation estimated by a logit regression is denoted in equation (3).

$$Moved(x)_{it} = \beta_0 + \beta_1 treated_i + \beta_2 after_t + \beta_3 treated * after_{it} + \beta_4 control * after_{it} + \varepsilon_{it} \quad if \quad year \leq 2008 \qquad (3)$$

Where

$Moved(x)_{it}$	is the logit loop variable denoting a change of location compared to a previous location: country in model (1), city in model (2) and firm in model (3)
β_0	is the constant
$\beta_1 treated_i$	is the dummy for the treatment group
$\beta_2 after_t$	is the dummy for the observations after the critical date
$\beta_3 treated_i \; x \; after_t$	is the difference in difference coefficient
$\beta_4 control \; x \; after_{it}$	is the change in the control group
ε_{it}	is the error term

β_3 is the coefficient that will reveal information about the internal job situation of critical employees for future success of the companies. Equation (3) uses access to inside information not yet examined before. The findings of these analyses are presented in the next section of this paper.

The regression results include a variable, *year,* serving as time-trend control. This variable starts with 2001 and increases linearly per year. In addition, this paper will carry out a robustness check where this control is replaced by time-fixed effects control, with variables *y2001* to *y2012* as time dummies.

Descriptive statistics

This section is devoted to the discussion of the results of the analysis performed by this paper. Firstly, an overview of the data characteristics is presented and a comparison with general economic data is made. Secondly, an in-depth analysis as outlined in the previous section is performed and exhibited, followed by a discussion of the results.

Table 1. Number of patents per country, 2001-2012

Country	Number of inventors	Number of inventors including unique inventors
Austria	1,672	2,722
Belgium	2,023	2,777
Germany	17,863	22,442
Denmark	2,587	3,254
France	8,945	12,231
Great Britain	9,412	12,845
Italy	3,735	5,230
Netherlands	1,576	2,650
Sweden	2,488	3,378
Switzerland	4,541	5,634
Europe total	58,763	79,661
China	1,971	3,475
India	3,033	4,839
Japan	15,037	21,121
United States	149,655	190,857

In table 1, a brief overview of the number of inventors applying for patents in the pharmaceutical industry in the ten biggest European countries (this paper will not distinguish between EU and non-EU nations). This table has to be treated with caution: the numbers do not represent the total number of patents, but the number of inventors involved in the application process, many of whom work on patents with more than one person. Because this paper is interested in behavior of inventors and not in the number of patents, it has chosen to present the data in this manner. However, due to the size of the sample, the ratios between countries as measured by patent applications in this industry correspond within bounds with the numbers presented in table 1.

The four biggest non-European nations are also included. The biggest missing European country is Spain. Despite being the fifth-largest European nation (excluding Russia and Turkey) by population, it slots in as only the eleventh most prolific country by number of patent applications (it should be noted that including inventors only applying once, Spain would occupy ninth place, above Denmark and The Netherlands). The other countries appear in approximately their expected position, based on population and GDP. Germany is the European leader of applications and is the only European country with more applications than Japan. Sweden, Switzerland and Denmark are punching above their weight with the number of applications, at the cost of countries like Greece, Portugal and the Netherlands. Outside of Europe, it is clear that the United States is the most prolific applicant for patents in this sector by a factor nearly ten times as large as the number two. In the literature review it became clear that most of the research on this topic focused on the US and these numbers are a justification of that singular attention. China and India, the two largest countries of the world by population size and both members of BRICS, the group of fast growing economies, still lag behind on the innovative front. China overtook Japan as the largest Asian economy in 2010[3], but these numbers indicate that the size of the economy does not necessarily correspond with the capabilities of the high-tech sector.

Figure 1 visualizes the trends in patent applications over the 10 complete years in the sample. Both the number of inventor applications and the number of patent applications are included (a table is included in the appendix). In all of these years, the number of patent applications is between three and four times smaller than the number of inventor applications, which indicates that the development of a product that warrants patenting in the pharmaceutical industry is very much a collaborative effort. As was discussed in the literature review, this is an important reason why intra-company diversity was found to have a positive effect on the effectiveness of the innovate efforts.

[3] http://online.wsj.com/articles/SB10001424052748703361904576142832741439402

There are some noticeable variations in the number of applications per year. The high point of the number of applications was 2003. This peak was followed by a substantial drop before stabilizing at a rate of approximately 10,000 patent applications per year. The size and relative stability of the number of applications per year indicates that the sample is reliable and large enough to use this sample as the basis of the analysis of this paper.

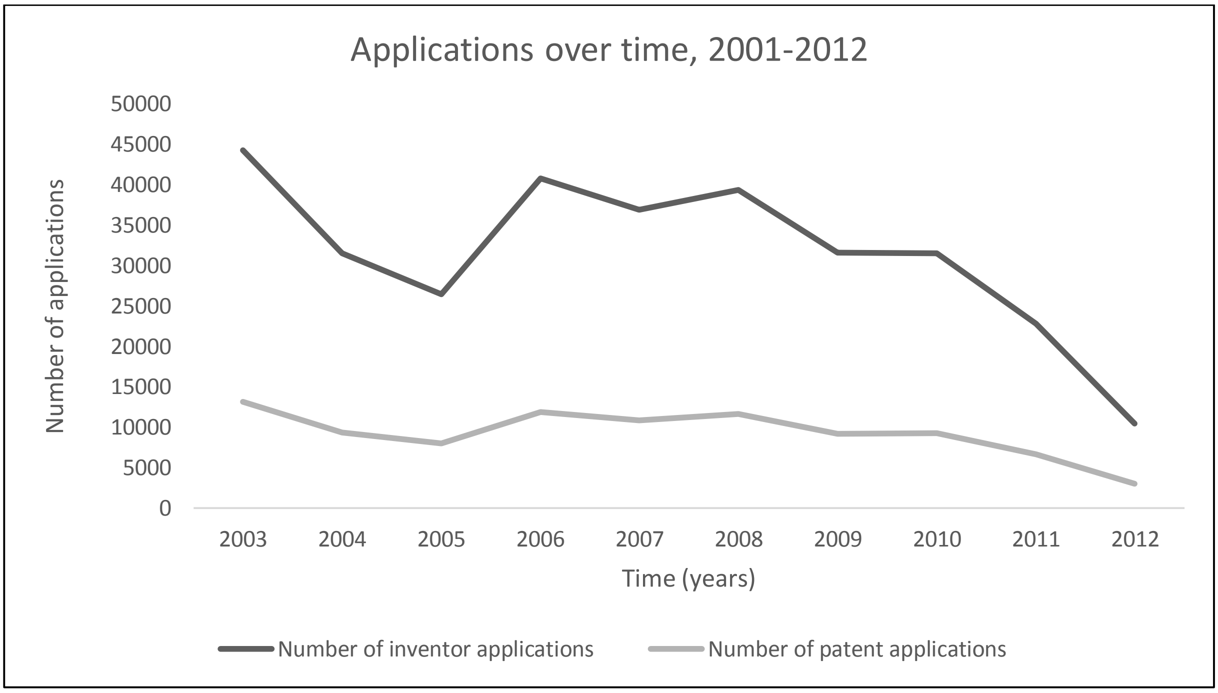

Figure 1. Applications over time, 2001-2012

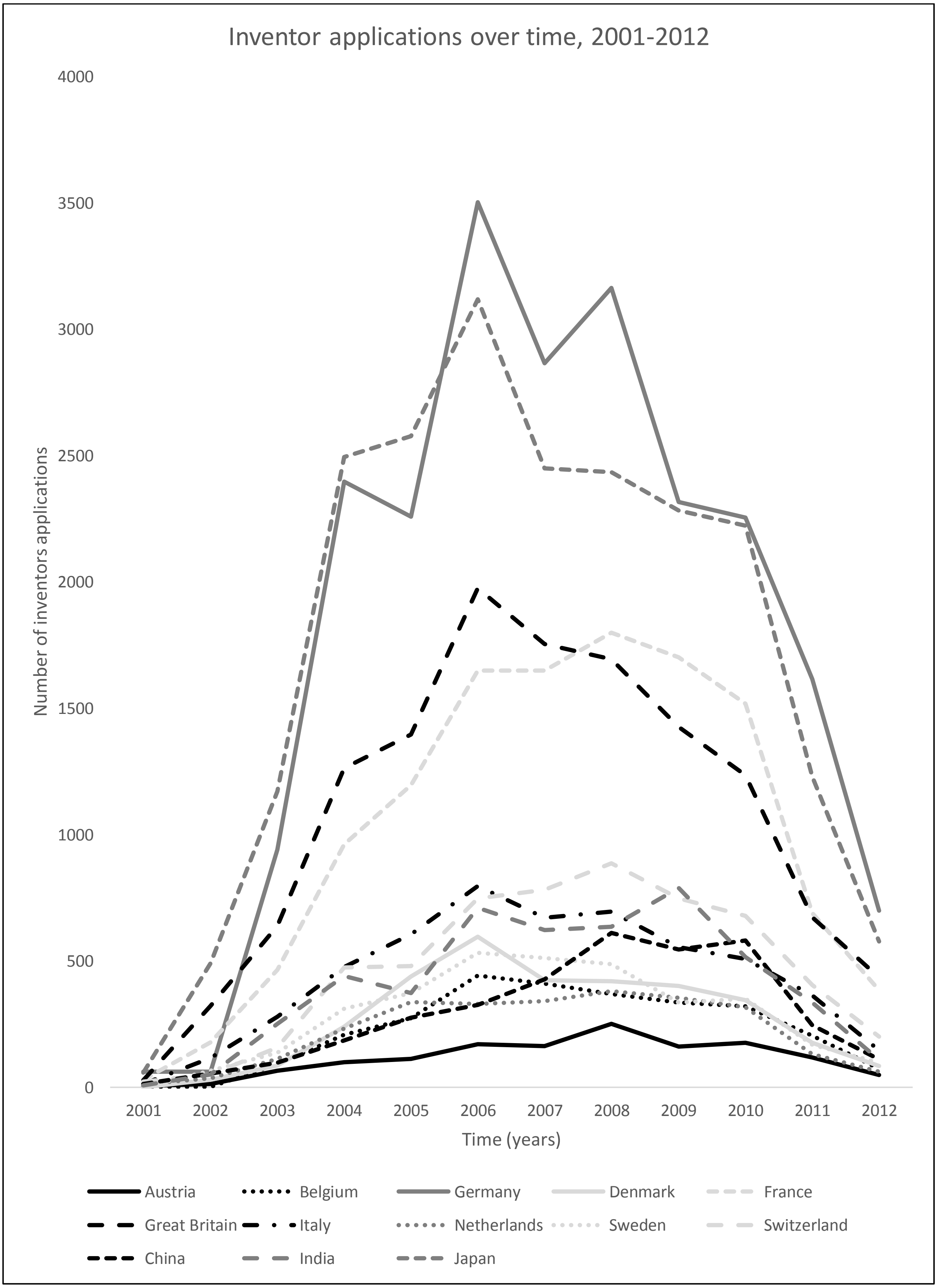

Figure 2. Inventor applications over time, 2001-2012

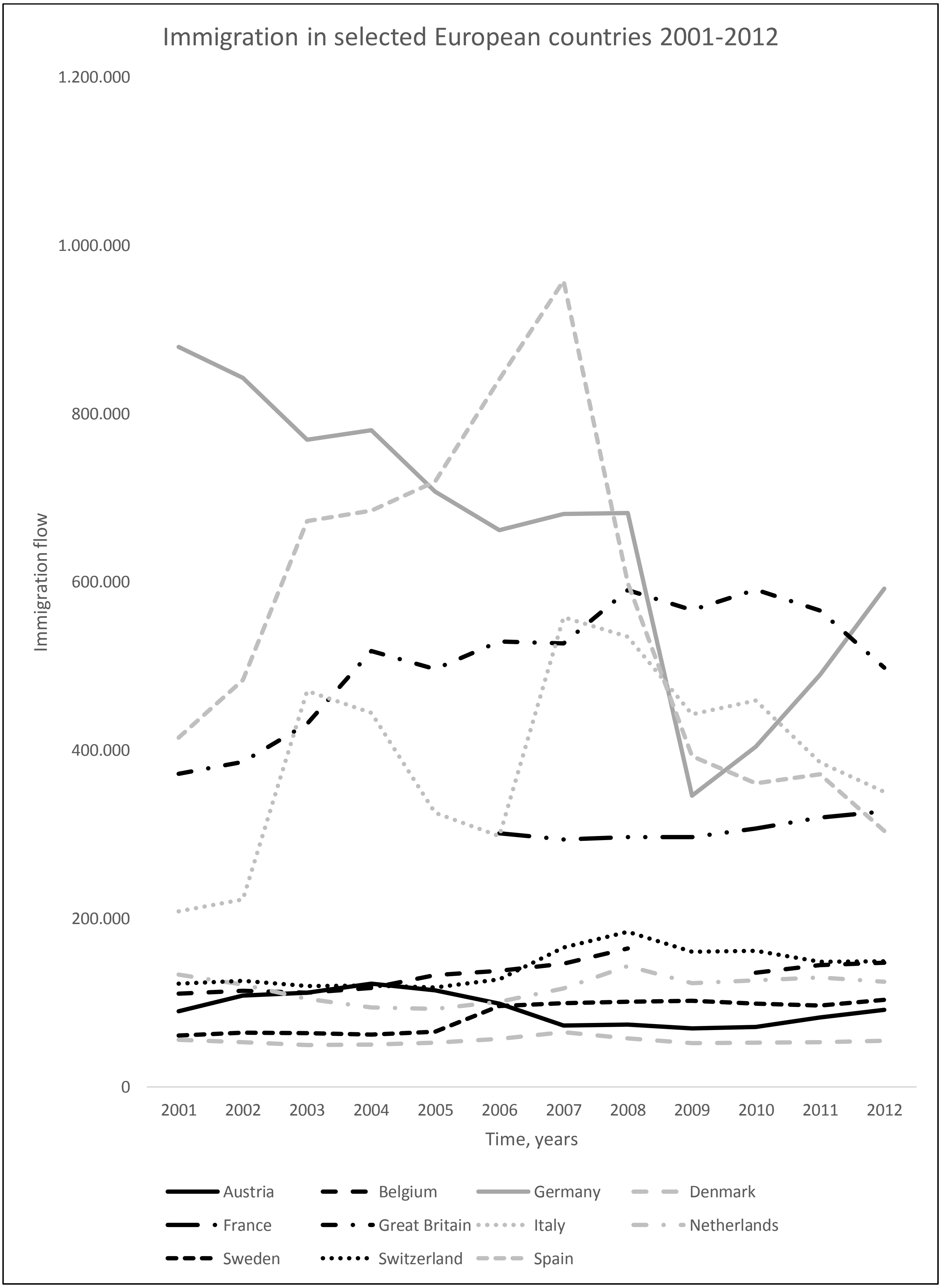

Figure 3. Immigration flow per year in selected European countries. Source: Eurostat

Figure 3 details the trends in general immigration in selected European nations during the time period of the sample. The data, provided by EU affiliate Eurostat, is available in table form in the appendix. The data only includes permanent immigration: temporary job contracts are not included. These temporary contracts are very popular among skilled workers and researchers: it gives this highly skilled group a chance to migrate to a country when an opportunity presents itself (for example a university grant or a temporary business collaboration). Despite this, general trends are expected to follow similar patterns, because the appeal of temporary as well as permanent residence is dependent on the same factors and trends.

One trend is clearly distinguishable: many countries registered a drop in immigration after 2007, when the financial crisis hit European nations. Some nations implemented policies to protect domestic jobs, in other countries economic circumstances worsened, making it less appealing for immigrants to settle. A second observation concerns the geographical position of nations: Spain was the top receiving country between 2005 and 2007 and Italy is consistently among the highest ranked countries too. Based on this data, Southern European nations bordering the Mediterranean Sea appear attract a lot of African immigrants, but this attraction is highly volatile and dependent on the economic well-being of the country, as demonstrated by the drop in registered immigrants entering Spain after 2007. On the other hand, a country that suffered a less severe economic downturn, Germany, is leading the immigration ranking for the first time in 2012. Thus, general immigration patterns are likely to depend on many variables (war and conflict in surrounding areas since the Arab spring is likely to influence the future trends of this graph), but the economic situation of the destination nation is deductible from figure 3.

Compared to immigration in Europe, immigration in the US is more stable (the data on US immigration is provided by US Homeland Security and included in the table provided in the appendix). Apart from a drop in the early 2000s the immigration figure remains stable at just over 1 million immigrants entering the country per year. Due to the different geographical location of the US, immigration is expected to be less related to short-term economic and societal changes in the rest of the world.

As is to be expected, the most popular places of residence for inventors are the biggest cities in Europe. Paris, the French capital, leads the table with 1,353 patent applications, followed by Berlin (1,172 applications) and Basel (985). Other economic centers such as London, Barcelona, Madrid, Vienna and Milan are also prominently featured in the ranking (a summarized ranking of the top European cities and selected peers is available in the appendix). In Germany, many of the applications are divided between different cities in the economic heart of the country, the Ruhr area. By comparison, in the US the clear number one city in number of applications (5,850) is San Diego, California, tops the table with 200% more applications than runner-up San Francisco (2,670). At first glance, it may appear that in many countries, the pharmaceutical industry is geographically clustered in major cities or innovative areas.

The biggest pharmaceutical companies are well-represented in the sample. Despite the limitations noted in the data discussion, it is possible to locate the biggest companies in the industry by examining the number of patent applications in the sample. In the appendix, a list of the number of patents for the largest 50 companies[4] is available. In table 2, the ten biggest European companies and their five largest international peers are displayed with their total number of patent applications.

[4] Ranking of 2013 Pharm Exec report accessible (and last accessed on September 30, 2014) at http://www.pharmexec.com/pharmexec/article/articleDetail.jsp?id=815158

Table 2. Ten largest European pharmaceutical companies by revenue and five international peers

Company	Country	2012 Sales (USD millions)	2012 R&D (USD millions)	Number of inventor applications	Number of patent applications
Novartis	Switzerland	45,418	8,831	946	271
Sanofi	France	38,370	6,117.8	2,020	505
Roche	Switzerland	37,542	8,032.2	389	141
GlaxoSmithKline	Great Britain	33,107	5,255.7	435	123
AstraZeneca	Great Britain	27,064	4,452	1,937	556
Bayer	Germany	14,734	2,522.7	2,655	556
Boehringer Ingelheim	Germany	13,686	3,012	3,132	770
Novo Nordisk	Denmark	13,478	1,882.3	809	237
Laboratories Servier	France	4,931	1,232.7	246	60
Actavis	Switzerland	4,716	401.8	89	27
Pfizer	USA	47,404	7,046	1,069	350
Merck*	USA	41,143	7,911	1,212	337
Johnson & Johnson	USA	23,491	5,362	25	19
Abbott	USA	23,119	2,900	1,552	350
Eli Lilly	USA	18,509	5,074.5	324	97

*Including Germany subdivision separately listed on ranking

Most of the companies exhibited in table 2 are true multinationals. The fact that their headquarters are located in a specific country is no true indicator of the location of the patent applicant. However, the data shows a correlation between the home country of the company and origin of patent applications. It should also be noted that more than half (160,696) of the observations in the sample are not applications under a company umbrella and are done on personal basis. In total, 122,219 applications are originating from a company or institution: many public services, chief among which hospital research centers, also apply for patents, but do so on a smaller scale than pharmaceutical companies. The companies displayed in table three show a loose correlation between 2012 sales and the number of applications. The same holds for the investment in research and development (R&D). It is imperative to point out that the 2012 sales and R&D investment figures are just a spot in time and the patent applications are a cumulative over multiple years (and many, especially in the early years of the sample, will be the result of investment before the year 2000). However, the Pharm Exec report points out that the ranking is relatively stable over time.

Table 3 gives a comprehensive overview of the trends in inventor mobility in the pharmaceutical industry, based on the patent application data. When an inventor is marked as having moved in a certain year, it means the inventor is present in the dataset in the year of interest and in any of the three years following it, but in two different locations. When the inventor did not move, the inventor is also present in the year of interest and in any of the three years following the year of interest, but is applying from the same location. For example, an inventor who applied in 2001 from the USA and in 2003 from Germany will be labeled a mover in the year 2001. Thus, the choice of three years between patent applications as an indicator for movement within that period is a compromise: a larger time gap would increase the number of movers, but decrease the accuracy of the time of movement, thus preventing an analysis on the time of movement, crucial to the understanding of the influences of movement patterns in the industry. It should also be noted that for the last year of the table, 2010, only information from two instead of three following years is available. Hence, the number of movers represented by this year is expected to grow, but is included because of its timely information.

Different variables for movement are used. In table 3, differences in geographical locations are used as indicator. When an inventor moves between countries, the chance of internal redeployment to a different position in the company or a change of jobs is more likely than the case where an inventor moves between cities: if the inventor moves between neighboring cities, it is impossible to state that this move is meaningful for his career or for patterns in migration. Because of this limitation, multiple variables are used, including the geographical ones, but also the variable for movement across firms (which comes with its own limitations, which will be expanded upon later in this section). The most notable first observation is the existence of a large spike in movements across countries in the early years of the sample. The number of movements across towns also piques in these years, but the difference between maximum and minimum is a lot less striking than for movements across nations. It appears that a significant part of the mobility of inventors in the early years of this century was cross-country movement.

Table 3. Mobility of inventors as % of total, 2001-2012

Country	Moved country as % of total, per country	Moved city as % of total, per country
Austria	2.24	13.81
Belgium	2.15	13.06
Germany	1.60	11.49
Denmark	1.45	12.65
France	1.26	12.26
Great Britain	2.40	19.52
Italy	0.99	16.94
Netherlands	1.46	9.07
Sweden	2.53	9.98
Switzerland	3.04	11.79
Spain	1.56	10.81
China	7.58	14.51
India	1.56	16.51
Japan	0.53	18.50
Korea (South)	0.82	13.69
United States	0.71	9.83
Europe total	1.81	13.40
Total	4.61	13.80

Inter-European movement (full table available in appendix) can be measured separately. It is a more precise way of measuring European movement, because it measures how many inventors moved between countries out of all inventors applying for patents out of Europe. This statistic yields the most informative measurement of mobility within Europe, but considers inventors that moved to or from a country not in Europe are counted as non-movers. The share of movers as a percentage of total is stable, hovering around and generally just above 2% of total inventors in Europe (the years of movement for 2010 again is limited to two instead of three). There is no trend visible and movement within Europe appears to be unrelated to the patterns visible in the worldwide sample.

Table 3 exhibits the amount of movements per country as a percentage of the total number of applications. The patterns for individual nations reflect the previously discussed general patterns of movements between countries and cities. As established these are the ten biggest nations in terms of relevant patent applications, plus Spain. Some general remarks can be made. It is not surprising that the movement across countries is higher in Europe due the smaller geographical distances and the open borders between EU members and selected affiliates. More notable is the larger inter-city mobility in Europe compared to the US. One explanation for the low mobility between cities in the US could be the different spatial history of the two continents: in Europe, large urban areas are often formed by a cluster of historically separate city, whereas many large urban areas in the US grew from the inside out, meaning the entire area carries the same name. The rest of the world, with developed nations like Japan and South Korea as special interest, are closer to Europe than to the US.

Within Europe, the real terrain of investigation for this paper, Great Britain is in the top-3 of countries with most cross-border movements. It is the only large European nation near the top of the ranking. Smaller nations such as Switzerland, Sweden, Austria and Belgium inhibit the top positions. Three of these four countries are bordered by at least two larger countries. Within Europe, the countries with the lowest mobility rate between countries are Italy and France respectively. Causes of this phenomenon can be multifold. Firstly, it could be a result of effects this paper hypothesizes about. Secondly, the International Chamber of Commerce states that France and Italy are among the least economically open countries in Europe[5]. Thirdly, these two countries score lowest in the English Proficiency Index report presented by EducationFirst (EF)[6], though it is to be expected that highly skilled inventors are not representative of the entire population in this regard. It is impossible to reliably infer the dominant reason and it is likely that these factors combined reinforce and complement each other.

It is a different story for cross-city mobility. Once more Great Britain is the most mobile nation of the big countries and this time also of the entire European sample. If one would expect that most inventors would concentrate in the city of London, it appears that there are multiple British locations where inventors can live and be productive. Of course, it should be kept in mind that this can mean that inventors are merely relocating, for example, from London to surrounding areas where the rent may be cheaper and the quality of living may be higher.

[5] Report accessible at: http://www.iccwbo.org/Data/Documents/Global-Influence/G20/Products/2013-Open-Markets-Index-(OMI)-low-resolution-pdf/ (last retrieved September 30, 2014

[6] Latest report accessible at: http://www.ef.nl/epi/downloads/ (2013 report last retrieved September 30, 2014)

Despite that, the high mobility across cities in Great Britain is a surprise, especially when compared to polycentric countries such as Germany. The Ruhr area is comprised of multiple cities of moderate size, several of which are home to a significant amount of inventors (table 2), but the close proximity of these cities does not result in a high intra-country mobility for Germany. Similar to its position in the inter-country ranking, the mobility of inventors in Germany is below the European average. A country for which the opposite holds is Italy. Coming last in the inter-country ranking, it sees a lot of internal mobility. Italy is a country in which economic prosperity is imbalanced between South (comparatively poor by European standards) and North (comparatively rich by European standards). Another observation is that large countries such as Great Britain, Italy and France do see significant internal mobility, but these numbers do not give an indication that country size is the dominant factor influencing internal mobility. Switzerland, Austria, Belgium and Denmark are in similar positions as in the international mobility ranking.

Table 4. Inventor mobility for largest European inventor cities and selected international peers, 2001-2012

City (European)	Moved city, % of total	City (Rest of world)	Moved city, % of total
Aachen	1.90	Beijing	9.54
Barcelona	6.13	Hyderabad	8.75
Basel	12.84	New York	7.07
Berlin	3.05	Osaka	21.81
Biberach	11.64	San Diego	7.24
Cambridge	13.44	San Francisco	8.11
Darmstadt	8.09	Seoul	7.53
Essex	26.81	Shanghai	6.98
London	9.84	Singapore	12.20
Lyon	7.56	Tokyo	10.22
Madrid	6.81	Toronto	8.33
Milano	13.97	Vancouver	7.87
Paris	6.30		
Vienna	10.96	Europe total	12.63
Wuppertal	8.84	Total	12.96

When examined at the city level, a similar picture emerges (table 4). The results confirm that the average mobility rate in Europe is slightly lower than the world average. There are three clear outliers. The European cities Aachen and Essex see a very low and very high rate of mobility respectively and the Japanese city Osaka sees an inventor mobility rate higher than 20% too. The largest two European cities, London and Paris, see a below average mobility rate, whereas smaller cities such as Basel, Essex and Cambridge show inventor mobility rates higher than the European average. In this respect, the biggest outlier is Milan as one of the largest metropolitan areas, but with an inventor mobility rate higher than average, contrary to the pattern for other large cities. In the rest of the world, most mobility rates are in the same percentage band. The biggest outlier is the aforementioned city of Osaka (located in a polycentric metropolitan area which might induce movements to different cities over small distances). Interestingly, this city is also the only city with a higher mobility rate than the world average rate, giving rise to the hypothesized idea that large cities are negatively correlated to inventor mobility.

Finally, table 5 and figure 4 displays the inventor information of applications from and inventors employed by the largest pharmaceutical companies. As discussed in the data review section, this data should be approached with caution due to its incomplete nature. In general, it is to be expected that the rate of mobility is a bit higher in the data sample than in reality, due to the way in which an error in a company name could result in a difference between company names for two applications for the same inventor. Due to the length and variety of company names as compared to city or country names, this data is less reliable than the city and country comparisons, but still holds information on inventor mobility.

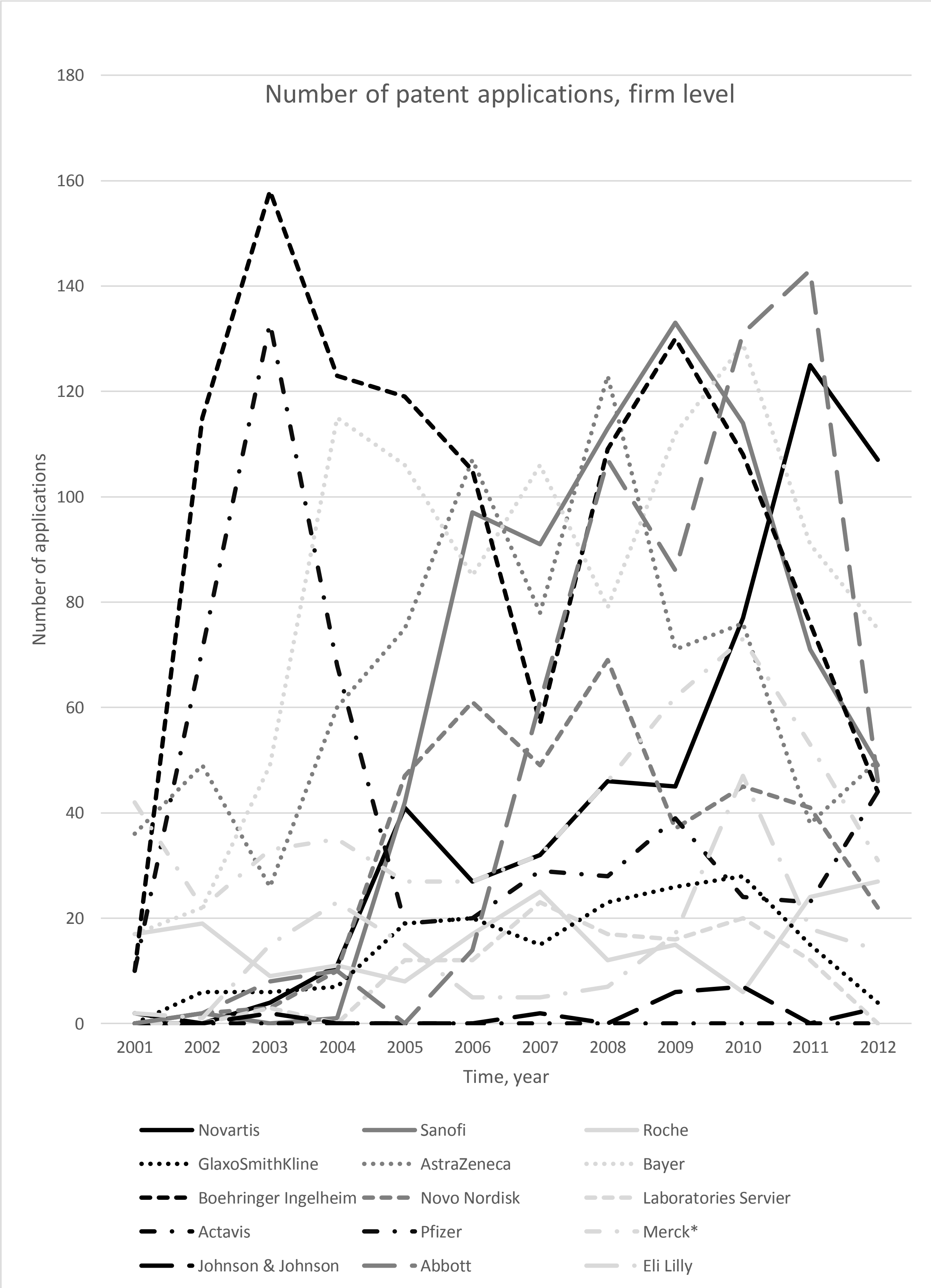

Figure 4. Number of relevant inventor applications for major companies 2001-2012

Figure 4 also proves that data in the early years of the dataset is spotty: some European firms miss company information in the first three years. No real trends are visible in the graph showcasing the number of relevant inventor applications. Table 7 exhibits information about the mobility for the largest companies (see table 3). There is a lot of variation between the companies, but only three companies have mobility rates higher than the average for the entire sample: Bayer and Boehringer see more than one percentage point higher mobility rates and the rate for Sanofi is very similar to the overall rate. Several of the largest companies see mobility rates several percentage points below the average rate, including the largest companies Pfizer and Novartis.

Table 5. Mobility of inventors as % of total of of largest companies

Company	Mobility of inventors, % of total
Novartis	4.47
Sanofi	12.06
Roche	7.65
GlaxoSmithKline	5.88
AstraZeneca	7.13
Bayer	13.59
Boehringer Ingelheim	13.57
Novo Nordisk	12.69
Laboratories Servier	2.61
Actavis	0
Pfizer	2.17
Merck*	8.70
Johnson & Johnson	0
Abbott	3.13
Eli Lilly	1.18
Total	12.01

Empirical results

In this section the results of the empirical analysis conducted by this paper are discussed. Multiple regression results will be discussed, in support of the hypotheses stated by this paper. After a brief discussion of the analysis and its implications for the hypotheses, a general discussion about where the results fit in with respect to existing literature and knowledge will be held. Because of the advantages and disadvantages of each measurement of movement as discussed in the methodology section, each regression will be performed on three models, consistently displayed as (1) inventor moved between countries, (2) inventor moved between cities and (3) inventor moved between firms. This robustness in analysis means the big worry of unique errors in the dataset, as well as outliers in one of the three models, will be uncovered when these problems start plaguing the regression results in one of the models.

Table 6 displays the results of a regression performed on the complete relevant dataset, with variable *english* denoting countries where English is the primary language[7]. Additional variables include *year,* the time-trend control variable that controls for normal changes over time and thus in this regression acts as grab bag for changes in inventor mobility not investigated, and the variable *openness,* the variable discussed in the data section that measures economic changes in individual nations and acts as a control for individual shocks. A negative coefficient is found for all three models, indicating that being an English-speaking nation has a negative effect on inventor mobility. Foreign immigration and home-grown movements do not result in a higher mobility rate for these countries, thus hypothesis 1, stating that being English has a positive effect on inventor mobility, must be rejected.

A before and after scenario is now used. Every observation after and including 2008 is treated as after. This construction allows formal testing to answer the next hypotheses.

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[7] Australia, Great Britain, Canada (including French-speaking part) and the United States are included in this dummy variable.

Table 6. Logit regression of inventor mobility between country (1), city (2) and firm (3), 2001-2012

	(1)	(2)	(3)
	Moved Country	Moved City	Moved Firm
VARIABLES	moved_3	moved_3	moved_3
english	-2.506***	-0.841***	-0.129***
	(0.0439)	(0.0171)	(0.0175)
year	-0.0634***	-0.0896***	-0.0747***
	(0.00506)	(0.00280)	(0.00274)
openness	-0.0338***	-0.00462***	0.00194***
	(0.000724)	(0.000298)	(0.000268)
Constant	125.7***	178.3***	147.8***
	(10.13)	(5.615)	(5.491)
Observations	137,263	137,263	137,263
City FE	YES	YES	YES
Inventor FE	YES	YES	YES

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7. Logit regression of inventor mobility between country (1), city (2) and firm (3), 2001-2012

	(1) Moved Country	(2) Moved City	(3) Moved Firm
VARIABLES	moved_3	moved_3	moved_3
southern	-1.147***	-0.145***	0.193***
	(0.146)	(0.0528)	(0.0522)
after*southern	0.222	-0.361	-0.189
	(0.557)	(0.231)	(0.215)
openness*(after*southern)	0.00550	0.00499	-0.000357
	(0.00767)	(0.00332)	(0.00309)
after*europe	-1.991***	0.113	0.118
	(0.305)	(0.137)	(0.125)
openness*(after*europe)	0.0366***	-0.00224	-0.00261**
	(0.00322)	(0.00145)	(0.00127)
after	-1.342***	-0.517***	-0.0822**
	(0.0703)	(0.0344)	(0.0339)
europe	0.182**	-0.202***	0.0636
	(0.0909)	(0.0398)	(0.0392)
english	-2.489***	-0.919***	-0.108***
	(0.0480)	(0.0187)	(0.0199)
year	0.0622***	-0.0305***	-0.0633***
	(0.00805)	(0.00454)	(0.00455)
openness	-0.0392***	-0.00334***	0.00176***
	(0.00115)	(0.000423)	(0.000357)
Constant	-125.8***	60.01***	125.0***
	(16.12)	(9.096)	(9.112)
Observations	137,263	137,263	137,263
City FE	YES	YES	YES
Inventor FE	YES	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

In continuation of the analysis presented in table 6, in table 7 it is established that being an english speaking country is a negative influence on movement across country (-2.545), city (-0.920) and firm (-0.107), all strongly significant on the 1% level, further supporting the rejection of hypothesis 1.

Continuing the discussion of the results presented in table 7, the variable *after*europe* takes a negative and significant value when looking at movement across countries (model 1). The variable is non-significant and close to neutral for movement across cities (model 2) and also non-significant and negative for movement across firms (model 3). The variable *after* is negative for all three models, strongly significant on the 1% level for model (1) and (2) and significant on the 5% level for model (3). Furthermore, the variable *europe* is positive and significant on the 5% for model (1), but negative and strongly significant on the 1% level for model (2). Multiple implications can be drawn from this. Firstly, all three models support hypothesis 2, based on this regression the hypothesis stating that inventor mobility is negatively affected by the financial crisis, starting in 2008, cannot be rejected.

Secondly, the evidence on the impact of Europe as compared to the rest of the world is inconclusive: denoted by *after*europe,* European inventors moved less across countries since 2008, but judging by model (2) and (3), movement across cities and firms did not change significantly. It could be concluded from this evidence that large movements continue to occur, but small career changes became more difficult. Overall, hypothesis 3, stating that mobility in European nations is more affected by the financial crisis, has to be rejected, even though part of the evidence supports it.

The variables *southern* and *after*southern* are dummies for the Southern European nations (France, Greece, Ireland, Italy, Portugal and Spain). The result for *southern* is negative and highly significant at the 1% level for country and city and highly significant and positive for firm, but no extra effect is noticeable after the financial crisis hit these countries in 2008: *after*southern* is insignificant for all three models. Hence, there is no evidence that inventors in the countries with the largest economic shock behave differently than their counterparts in Northern Europe, thus hypothesis 4 is rejected. Despite that, it should be noted that there is a significant difference in inventor behavior between Southern and Northern Europe for the duration of the data sample.

Table 8 presents the regression corresponding to hypothesis 5. As was expected, the size of the city is negatively correlated to the movement of inventors in two of the three models, only movement across firms is positively correlated to the size of the city. However, the financial downturn has no additional negative or positive effect when using the models (1) and (3) for large cities. On the other hand, a positive and highly significant effect is found between movement across cities and city size. Thus, after 2008, inventors already living in large cities switched more between cities. The evidence in support of hypothesis 5, the hypothesis that city size had an additional negative effect after the financial downturn has to be rejected.

Table 9 provides support for the last hypothesis. Large firm (*largefirm)* is positive and highly significant for movements across (1) country and (2) city, but returns insignificant for (3) company. It indicates that firm size has a positive effect for geographical movements, but that firm size does not matter when switching between firms. There is no significant effect for any of the models (1), (2) and (3) after 2008, large firms do not prove to be negatively correlated with movement across countries, cities and firms. Thus, hypothesis 6 stating that movement across firms will fall after 2008 needs to be rejected.

Table 8. Logit regression of inventor mobility between country (1), city (2) and firm (3), 2001-2012.

	(1) Moved Country	(2) Moved City	(3) Moved Firm
VARIABLES	moved_3	moved_3	moved_3
largecity	-0.848***	-0.552***	0.212***
	(0.197)	(0.0831)	(0.0691)
after*largecity	1.218	1.884***	0.130
	(1.176)	(0.510)	(0.413)
openness*(after*largecity)	-0.0203	-0.0313***	-0.00781
	(0.0213)	(0.00889)	(0.00675)
after	-1.094***	-0.551***	-0.126***
	(0.0630)	(0.0310)	(0.0308)
europe	-0.154**	-0.216***	0.0731**
	(0.0718)	(0.0320)	(0.0316)
english	-2.544***	-0.917***	-0.105***
	(0.0463)	(0.0187)	(0.0199)
year	0.0376***	-0.0287***	-0.0597***
	(0.00787)	(0.00446)	(0.00447)
openness	-0.0334***	-0.00343***	0.00130***
	(0.00103)	(0.000391)	(0.000340)
Constant	-76.44***	56.39***	117.9***
	(15.76)	(8.923)	(8.959)
Observations	137,263	137,263	137,263
City FE	YES	YES	YES
Inventor FE	YES	YES	YES

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9. Logit regression of inventor mobility between country (1), city (2) and firm (3), 2001-2012.

	(1) Moved Country	(2) Moved City	(3) Moved Firm
VARIABLES	moved_3	moved_3	moved_3
largefirm	0.273***	0.207***	0.0427
	(0.0853)	(0.0539)	(0.0596)
after*largefirm	-0.379	0.0831	-0.264
	(0.288)	(0.162)	(0.182)
openness*(after*largefirm)	0.0143***	-0.00279	-0.00258
	(0.00424)	(0.00211)	(0.00229)
after	-1.115***	-0.538***	-0.117***
	(0.0639)	(0.0312)	(0.0308)
europe	-0.292***	-0.295***	0.100***
	(0.0713)	(0.0312)	(0.0308)
english	-2.542***	-0.919***	-0.105***
	(0.0464)	(0.0187)	(0.0199)
year	0.0378***	-0.0310***	-0.0596***
	(0.00790)	(0.00446)	(0.00448)
openness	-0.0334***	-0.00304***	0.00126***
	(0.00105)	(0.000385)	(0.000340)
Constant	-76.92***	61.03***	117.5***
	(15.83)	(8.924)	(8.964)
Observations	137,263	137,263	137,263
City FE	YES	YES	YES
Inventor FE	YES	YES	YES

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Robustness check

In addition to the data analysis presented above, selected robustness checks will be presented to solidify or challenge the main results.

Throughout the results, the variable *year* is used as a time trend control. However, because it is plausible that time does not necessarily follow a straightforward trend, an alternative in the form of a time fixed effects analysis is presented. In table 10 the variable *year* is replaced by year-specific dummies to create year fixed effects. Other than the different method of measurement for time impact, this regression is analogous to table 7.

The results from this regression corresponds to the results found in table 7. This confirms that a time trend control variable is reasonable to use for the analysis of this paper.

The next section is devoted to a discussion of the results found in this chapter.

Table 10. Logit regression of inventor mobility between country (1), city (2) and firm (3), 2001-2012 with year FE.

	(1) Moved Country	(2) Moved City	(3) Moved Firm
VARIABLES	moved_3	moved_3	moved_3
southern	-1.127***	-0.206***	0.147***
	(0.145)	(0.0528)	(0.0522)
southernafter	0.202	-0.296	-0.134
	(0.555)	(0.231)	(0.216)
openaftersouthern	0.00560	0.00492	-0.000542
	(0.00763)	(0.00333)	(0.00311)
aftereurope	-2.025***	-0.00873	0.0885
	(0.304)	(0.138)	(0.126)
openaftereurope	0.0369***	5.76e-05	-0.00122
	(0.00319)	(0.00145)	(0.00128)
after	-1.048***	-0.714***	-0.443***
	(0.0512)	(0.0230)	(0.0218)
europe	0.203**	-0.153***	0.0383
	(0.0914)	(0.0413)	(0.0402)
english	-2.443***	-0.927***	-0.136***
	(0.0487)	(0.0189)	(0.0198)
open	-0.0393***	-0.00574***	0.000194
	(0.00108)	(0.000435)	(0.000376)
Constant	-3.148***	-2.064***	-1.857***
	(0.117)	(0.0618)	(0.0497)
Observations	137,263	137,263	137,263
City FE	YES	YES	YES
Inventor FE	YES	YES	YES
Year FE	YES	YES	YES

Discussion of results

This section will discuss the results presented in the previous sections in context of economic theory and previously discussed literature. Limitations as well as further possibilities for research will be dealt with at the end of this chapter.

For most of the hypotheses stated by this paper, partial support was found. In fact, this paper only found full support for hypothesis 2: the data supports the expectation that the number of patent applications decreases starting in the year 2008. This being the broadest of all hypotheses of this paper, if no evidence for this hypothesis was to be found, the other findings would have lost weight no matter the result. The fact that patent applications decreased in the years following the financial downturn is not surprising for multiple reasons. Firstly, common sense dictates that with lessened economic prospects, firms will decrease their effort to pay now for possible future benefits. Secondly, previous literature predicted this decrease in patent activity. Archibugi et al (2013) already found a decrease in budget for innovation after the crisis and the decrease in patent applications is directly related to this tightening of resources.

Despite the logic behind these patterns, they do deserve attention. A decrease in patent applications for pharmaceutical categories does not only endanger future profitability of the sector, but also future progress in national health. It is to be expected that in the long term, returns on health investment are diminishing, since the most effective medicines (such as antibiotics) and treatments are already on the market. However, it could be that societal demand for research in health products actually increases to account for this expected decrease in effectiveness. A decrease in investment might accelerate the slowdown of medical breakthroughs, which, if this pattern is persistent, deserves to be a societal debate.

Hypothesis 1 was fully rejected. It stated that a country being English-speaking was expected to have a positive influence on inward mobility. In fact, the opposite effect was found. A number of plausible explanations can be given for this phenomenon. Firstly, it could be that the effect of immigrants from countries such as China and India is smaller than expected: the number of inventor applications from these countries was small. If many inventors from these countries first moved to English speaking countries like the United States and Great Britain for relevant studies, then stay there to start innovating, these individuals will not be captured as movers by the data. A small home sector may prevent many inventors from switching countries as they never got the chance to work in the home country. Secondly, the geographical step of mobility between these countries is much larger than the geographical step between bordering nations in the European Union, which accommodates cross-border movements with its policy of free movements of goods and people between member states and affiliates. One necessarily conclusion following from the observation that rejected the hypothesis is that the almost singular focus of the previously economic literature on the mobility situation in the United States is not always justified.

The understanding that English-speaking countries did not attract more inward mobility has implications for hypotheses 3, 4, 5 and 6. All these hypotheses had to be rejected, but the information obtained in combination with the rejection of hypothesis one is still valuable and sheds light on patterns in inventor mobility in the pharmaceutical industry. The fact that non-English nations do not attract less but more inventors means that cross-border or localized movement in Europe (where most significant non-English nations of patent applicants are situated) is a very significant part of the total movement in the continent.

Hypothesis 3 is one of the hypotheses for which the analysis yielded mixed results. The notion that European nations and especially the euro-zone suffered more from the economic downturn than much the rest of the world is well-documented and this paper expected that the mobility of inventors would follow this pattern. For the models that estimate mobility across countries, the data supports the expectation. This is in line with findings of Docqueir and Rapoport (2012) and Freeman (2010). Both reports found an increase of inventor mobility towards rich nations. When rich nations get comparatively less rich, a slowdown in immigration can be expected and was indeed found for mobility across nations. The analysis of mobility across cities and firms tells a different story and results in an overall rejection of the hypothesis, but it is imperative to recognize that patterns across firms do not necessarily perfectly correlate with patterns across countries: in case of the pharmaceutical industries, many firms are multinationals and can opt to internally relocate instead of hire, or vice versa. However, the finding that mobility across cities and firms is not affected as opposed to decreased or increased in context of the decrease of the other model could have a myriad of reasons and is likely a combination of more than one important market mechanism. Any attempt made at finding a satisfactory explanation based on this analysis would be based on guesswork.

Hypothesis 4, stating that Southern European nations were expected to lose more inventor mobility than Northern European nations, was not supported by data. Southern Europe was found to be less desirable than Northern Europe for the entirety of the dataset, without a significant decrease since the start of the financial downturn. It suggests that career prospects in the pharmaceutical industry are lacking for Southern Europe, not only because of the financial downturn, but because of more fundamental problems present in the entirety of the dataset. Murakas et al (2007) tried to find reasons which factors are important limiting reasons for inventors to move or stay in a country and two of the main reasons found were career prospects and the ease of working in the country. This suggests that Southern European countries suffer from a fundamental lack of attractiveness for highly skilled individuals, which is concerning in both the short and the long term. However, the downturn in attractiveness of the rest of Europe does give them chances to level the playing field.

Hypothesis 5 returns results similar in inconclusiveness to the results for hypothesis 3. Only movement between cities is differently affected by city size. This indicates that geographical change does not equate job change. Thus, when only partial evidence for a hypothesis is found, it could be that the models used do not measure the same thing, which would explain the contradictory result for hypothesis 3 and 5. Movement across cities increases more in large cities than in other places after the financial downturn, which could indicate that the largest cities, often home to headquarters of the biggest firms, are consolidating in those city and moving their operations to those concentrated places. A lack of significant movement across countries and firms and an increased movement to cities could plausibly be caused by inter-firm reorganizations.

The results obtained to investigate hypothesis 6, stating that mobility to large firms decreased more than mobility to other firms is rejected. Evidence from the model regressing mobility across countries, cities and firms indicates that no significant change in activity has resulted from the time period. The insignificance of the models does indicate that large firms do not differ in behavior from smaller firms. There is no evidence to suggest these firms can start looking for the best talent on the market wherever they are located, or stop hiring local and perhaps less gifted inventors, because they have the chance to cherry pick across nations due to the general decrease in mobility found in support of hypothesis 2. This finding does not confirm the results of a multitude of reports discussed in the literature review that found that immigrant inventors are more productive or earn higher wages. Hunt (2009 and 2013), No and Walsh (2010) and Chellaraj et al (2008) found this effect internationally, while the same effect was found by reports by Niebuhr (2010) and Lee and Nathan (2011) for European nations. Thus, this paper cannot support the existing scientific findings for this hypothesis.

This section has discussed the results of the analytical research of this paper and has tried to interpret it with support of existing literature. The next section will outline some of the shortcomings of this paper and recommendations for further research.

Recommendations and limitations

No scientific research comes without ifs and buts. In this section, limitations of this paper are outlined, as well as recommendations to address these problems.

The largest limitation of this paper is the current lack of deep knowledge about consequences of the financial downturn and how inventor mobility will react and fit into these changing circumstances. It is too early to predict long-term economic changes that result from this event. Selected literature tried to bring more understanding and this paper aimed to contribute, but as the economic shock is still ongoing and many of the effects are expected to have a lagged effect on companies and individuals, these findings should be treated with appropriate caution.

Following on that, the first and main recommendation for further research is one of patience. The topic of inventor mobility is relevant and exploiting patent application data to investigate this is one of the most elegant and efficient ways to uncover behavior of highly skilled employees in the innovative sector. The innovative sector is crucial to the economy and to future economic growth and more detailed information on motivations and limitations of this sector should constantly be incorporated in new scientific research.

A second limitation of this paper is that it focuses on only one sector of the economy: the pharmaceutical sector. This choice was defended in the introduction, but nevertheless it remains likely that different industries react differently to economic shocks. Thus, while this paper provides information on behavior of inventors, this information cannot be extrapolated to other industries before additional research is done on those industries. Because inventors in other industries are not as prolific as in the pharmaceutical industry, the method used in this paper is not as explanatory for these industries. To gain a fuller understanding of the world, alternatives ought to be found.

Conclusion

This paper contributed to the understanding of inventor mobility patterns by exploiting patent application data. Inward mobility across nations, cities and firms was analytically measured for inventors working in the pharmaceutical industry. The focus of the paper on the situation in Europe aimed to fill a void in existing literature and it used economic events, specifically the financial crisis that caused the economic downturn starting in 2008, to create a before and after scenario.

This paper found a decline in patent applications after the start of the economic downturn. Some support for more specific expectations was found, but the analysis in support for these hypotheses also brought to light that geographical inventor patterns often do not correspond to mobility between different firms. This paper found that geographical mobility across nations fell more for Europe than for the rest of the world and that city size was no factor for large geographical movements, but the model estimating movements between firms often contradicts the model for movement across nations. Southern Europe is at a consistent disadvantage compared to the rest of Europe, with less inward mobility to bolster their innovative sector. However, the fact that no additional effect was found after their deepening financial problems after 2008 should be somewhat encouraging for the longer-term prospects of their economies. No support for the expectation that mobility to large firms was more affected than to smaller firms was found. Finally, it was discovered that English-speaking countries do not attract more but less inward mobility than the rest of the world as opposed to the expectation of this paper.

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Appendix

Variables used

moved	Dependent variable, split up for use in three models.
moved country	Dependent variable denoting inventor movement between countries. Inventor flags as moved when patents are filed from two different nations with a maximum time period of 3 years
moved city	Dependent variable denoting inventor movement between cities. Inventor flags as moved when patents are filed from two different cities with a maximum time period of 3 years
moved firm	Dependent variable denoting inventor movement between firms. Inventor flags as moved when patents are filed from two different firms with a maximum time period of 3 years
english	Dummy variable taking value 1 if country is English-speaking. Includes Australia, Canada, Great Britain and the United States in this paper
openness	Continuous variable denoting performance of individual countries per year, measured by trade (imports and exports) as percent of GDP
after	Dummy variable taking value 1 if time in years is 2008 or later.
europe	Dummy variable taking value 1 if country is located in Europe
after*europe	Interaction dummy variable taking value 1 if country is located in Europe and application is in 2008 or later
southern	Dummy variable taking value 1 if country is located in Europe and disproportionately hit by the financial crisis, with countries Greece, France, Ireland, Italy, Spain and Portugal included
after*southern	Interaction dummy variable taking value 1 if country is located in countries marked by variable southern and application is in 2008 or later

largecity	Dummy variable taking value 1 if city is located in Europe and has more than 2 million inhabitants. Consists of London, Istanbul, Berlin, Athens, Paris, Madrid, Kiev and Rome
after*largecity	Interaction dummy variable taking value 1 if city is marked by variable largecity and application is in 2008 or later
largefirm	Dummy variable taking value 1 for large European firms. Consists of Novartis, Sanofi, Roche, GlaxoSmithKline, AstraZeneca, Bayer, Boehringer, Novo Nordisk, Servier and Actavis (for reference see table 3)
after*largefirm	Interaction dummy variable taking value 1 if firm is marked by variable largefirm and application is in 2008 or later
year	Time trend control variable ranging between 2001 and 2012
y20xx	Dummy variable to estimate time fixed effects taking value 1 per year, with xx ranging from 01 to 12
openness*(after*europe)	Interaction variable taking non-zero value if variable after*europe is one
openness*(after*southern)	Interaction variable taking non-zero value if variable after*southern is one
openness*(after*largecity)	Interaction variable taking non-zero value if variable after*largecity is one
openness*(after*largefirm)	Interaction variable taking non-zero value if variable after*largefirm is one

Table 11. Number of patent applications over time

Year	Number of inventor applications	Number of patent applications
2001	24,865	8,071
2002	32,069	9,875
2003	44,233	13,187
2004	31,489	9,379
2005	26,459	8,015
2006	40,794	11,909
2007	36,903	10,865
2008	39,372	11,682
2009	31,588	9,155
2010	31,520	9,257
2011	22,771	6,686
2012	10,449	2,992

Table 12. Total migration per country, Eurostat and US Homeland Security data

Country/Year	2001	2002	2003	2004	2005	2006
Austria	89.928	108.125	111.869	122.547	114.465	98.535
Belgium	110.410	113.857	112.060	117.236	132.810	137.699
Germany	879.217	842.543	768.975	780.175	707.352	661.855
Denmark	55.984	52.778	49.754	49.860	52.458	56.750
France						301.544
Great Britain	372.206	385.901	431.487	518.097	496.470	529.008
Italy	208.252	222.801	470.491	444.566	325.673	297.640
Netherlands	133.404	121.250	104.514	94.019	92.297	101.150
Sweden	60.795	64.087	63.795	62.028	65.229	95.750
Switzerland	122.494	126.080	119.783	120.188	118.270	127.586
Spain	414.772	483.260	672.266	684.561	719.284	840.844
United States	1058902	1059356	703542	957883	1122257	1266129

Country/Year	2007	2008	2009	2010	2011	2012
Austria	72.862	73.772	69.295	70.978	82.230	91.557
Belgium	146.409	164.152		135.281	144.698	147.387
Germany	680.766	682.146	346.216	404.055	489.422	592.175
Denmark	64.656	57.357	51.800	52.236	52.833	54.409
France	293.980	296.608	296.970	307.111	319.816	327.431
Great Britain	526.714	590.242	566.514	590.950	566.044	498.040
Italy	558.019	534.712	442.940	458.856	385.793	350.772
Netherlands	116.819	143.516	122.917	126.776	130.118	124.566
Sweden	99.485	101.171	102.280	98.801	96.467	103.059
Switzerland	165.634	184.297	160.623	161.778	148.799	149.051
Spain	958.266	599.075	392.962	360.705	371.331	304.053
United States	1052415	1107126	1130818	1042625	1062949	1031631

Table 13. Intra-European inventor movement

Year	Not Moved	Moved	Total	Moved, % of total
2001	95	1	96	1.04
2002	538	5	543	0.92
2003	1005	21	1026	2.05
2004	2456	55	2511	2.19
2005	2954	72	3026	2.38
2006	3575	80	3655	2.19
2007	3350	76	3426	2.22
2008	3506	80	3586	2.23
2009	2900	57	2957	1.93
2010	2908	37	2945	1.26

Table 14. Inventors moved country, per country, 2001-2012

Country	Not moved	Moved	Total	Moved, % of total
Austria	524	12	536	2,24
Belgium	1049	23	1072	2,15
Germany	6902	112	7014	1,60
Denmark	1091	16	1107	1,45
France	4235	54	4289	1,26
Great Britain	4686	115	4801	2,40
Italy	2005	20	2025	0,99
Netherlands	880	13	893	1,46
Sweden	1231	32	1263	2,53
Switzerland	1817	57	1874	3,04
Spain	756	12	768	1,56
China	1000	82	1082	7,58
India	1389	22	1411	1,56
Japan	9296	50	9346	0,53
Korea (South)	1695	14	1709	0,82
United States	69957	500	70457	0,71
Europe total	26775	494	27269	1,81
Total	130956	6322	137278	4,61

Table 15. Inventors moved city, per country, 2001-2012

Country	Not moved	Moved	Total	Moved, % of total
Austria	462	74	536	13,81
Belgium	932	140	1072	13,06
Germany	6208	806	7014	11,49
Denmark	967	140	1107	12,65
France	3763	526	4289	12,26
Great Britain	3864	937	4801	19,52
Italy	1682	343	2025	16,94
Netherlands	812	81	893	9,07
Sweden	1137	126	1263	9,98
Switzerland	1653	221	1874	11,79
Spain	685	83	768	10,81
China	925	157	1082	14,51
India	1178	233	1411	16,51
Japan	7617	1729	9346	18,50
Korea (South)	1475	234	1709	13,69
United States	63528	6929	70457	9,83
Europe total	23616	3653	27269	13,40
Total	118333	18945	137278	13,80