

The Influence of Higher Education on the National Innovation System in Portugal

by

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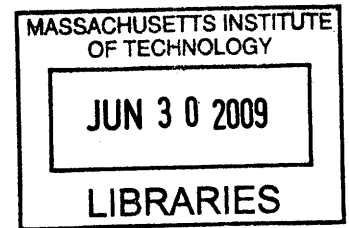
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Abstract

Many economists agree that countries wishing to develop their national economies should focus on increasing their innovation output. In recent years, the Portuguese government has pursued this goal, taking strides to improve the country's national system of innovation. This effort has included policy measures to increase the educational attainment of the Portuguese population and to improve the amount of collaboration between academia and industry in Portugal. Prior studies of locational effects have concluded that universities have a positive effect on the innovation output of the regions in which they are located. However, there is little understanding of how this locational effect varies with alternative types of higher education institutions, such as polytechnics and community colleges.

This thesis evaluates the co-locational effects of educational institutions and industry clusters on innovation output, and makes recommendations for how these results may be put to use, given the historical context of the Portuguese higher education system. The analysis is a comparative study of the geographic sub-regions within Portugal and the U.S. states of Georgia and Pennsylvania. The data used in the analysis includes industry data (enterprises, employment, and wages), educational data (number of graduates by field and type of institution), and innovation survey data.

The result of the co-location analysis shows that in Portugal, the technology-focused courses at universities and polytechnics are not concentrated in the same region as technological industry. However, the concentrations of university and polytechnic courses in Portugal frequently co-locate *with one another*, indicating an overlap in the regional offerings of these institutions. On the other hand, the states of Georgia and Pennsylvania show several instances of education-industry co-location in the technology sectors, with community colleges tending to co-locate with industry more than universities. The results show that, in both Georgia and Pennsylvania, co-locations between universities and industry occur more frequently in the research-focused Chemical/Pharmaceutical sector, while co-locations between community colleges and industry occur more frequently in the Equipment and Machinery sectors. A regression analysis of innovation survey data in Portugal observes no correlation between industry-academic co-location and innovation activity. However, I observe that the Community Innovation Survey dataset is not conducive to regression analysis.

The stated goal for Portuguese polytechnics is to serve industry needs and promote regional economic development. However, the results indicate that efforts to concentrate educational courses near industry clusters have not been successful. My most important observation from a policy perspective is that Portugal may be spreading its educational resources throughout its regions in ways that diminish the potential value of co-location and its potential value in innovation.

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Nomenclature / Terms

- AdI – Portugal’s Innovation Agency (Agencia da Inovação)
- CIP – Classification of Instructional Programs, used to classify U.S. higher ed. courses
- CIS – Community Innovation Survey
- CNAEF – National Classification of Fields of Education and Training, used in Portugal
- CORDIS – Community Research and Development Information Service,
superseded by PRO INNOV Europe
- EMU – European Economic and Monetary Union
- EPO – European Patent Office
- GDP – Gross Domestic Product
- HEI – Higher Education Institution, refers to all institutions of post-secondary education,
including universities, polytechnics, and community and technical colleges
- ICT – Information and Communication Technology
- KPF – Knowledge Production Function
- LBIO – Literature-Based Innovation Output
- LQ – Location Quotient
- MCTES – Portugal’s Ministry of Science, Technology, and Higher Education
- MNC – Multinational Corporation
- NACE – Classification of Economic Activities in the European Community
- NAICS – North American Industry Classification System
- NIS – National Innovation System – See “NSI”
- NSI – National System of Innovation
- NUTS – Nomenclature of Territorial Units for Statistics
- OECD – Organization for Economic Cooperation and Development
- OLS – Ordinary Least Squares
- PROINOV – Portugal’s Integrated Programme on Innovation
- SBA – United States Small Business Administration
- SME – Small and Medium Enterprises
- TFP – Total Factor Productivity
- USPTO – United States Patent and Trademark Office

1 Introduction

1.1 Background and Motivation

Portugal joined the European Community in 1986 and in the following years the Portuguese economy boomed, aided by generous European Union funding. In 1992, the economy fell into recession, but 1995 began a period of renewed economic vitality as the country's economic policy was shaped by preparations for its 1999 entry into the European economic and monetary union (EMU). Since joining the EMU, though, Portugal's growth has slowed dramatically. Portugal's average annual GDP growth for 2001-05 was only 0.6% versus a Euro-zone average of 1.4%. Portugal was distinguished in 2005 by having the lowest labor cost in the European Union, which should make the country an attractive location for manufacturing operations. But the country has not moved up the value-added chain in its traditional industries (such as textiles and footwear) and consequently it is facing increased competition from East Asian markets and from the lower wage costs of new Eastern European entrants in the EU. To remain economically competitive, Portugal is exploring newer sources of economic development.

Increasingly, economic development is driven by technological change and innovative activity. The legal, economic, and policy environments that comprise a country's National System of Innovation (NSI) influence its rate of technological change. In an effort to keep pace with its European peers, Portugal has turned its attention to improving its National System of Innovation. This focal shift began in 2001 with the launching of PROINOV, the Integrated Programme on Innovation, which had the objectives of promoting entrepreneurship and innovation, enhancing education and training, and improving cooperation between different institutions in Portugal's NSI (Simões 2001). PROINOV was abandoned with a government turnover in 2002, but its objectives were pursued by a smattering of disconnected policy initiatives. The next major innovation push was the Portugal's announcement in 2005 of its "Technological Plan". Among its main goals, the Technological Plan sought to increase the number of higher education graduates degrees and vocational trainees, and to increase R&D spending and knowledge generation. There is some concern, though, that these recent initiatives are "too little, too late." Typical indicators of innovation activity show that Portugal is still far behind its peers in many aspects of the knowledge economy. Without a continued focus and investment in innovation and education, Portugal may remain in this weak position.

In 2005, the Portuguese government began to acknowledge that, in general, their innovation governance system had been characterized by a ‘divide’ between science policy on the one hand, and industrial and enterprise policies on the other. This ‘divide’ has been translated into separate and independently operating programs for science and industry. Thus, another general policy goal that emerged in 2005 (as part of the Technological Plan and otherwise) was to bridge the gap between academic research and industry, through technology transfer and entrepreneurship programs. A consequence of this goal was the reorganization and redefinition of several government agencies within the Portuguese NSI. For one, the Ministry of Science, Innovation and Higher Education was restructured to be the Ministry of Science, Technology, and Higher Education.

Recognizing that the transition to a knowledge economy could involve far-reaching reforms of its higher education system, the Portuguese government sought external advice on how those education reforms should be approached. Among other external reviews, the Portuguese government commissioned the OECD Secretariat to conduct an overall evaluation of the country’s higher education system in the period 2005-2006. One of the more salient conclusions from the OECD report was that the binary divide (the differentiation between polytechnic institutions and universities) should be strengthened. The OECD recommended that Portugal clearly define the scope of universities and polytechnics (OECD 2007). As their evaluation put it, “the polytechnic role in the research space should not encroach on the university role but should be complementary to it, focusing rather on technology transfer and development.” A separate independent evaluation from PRO INNO Europe called for improving the cooperation between players in the NSI, specifically between higher education institutions and industry (Simões 2007).

Thus, it is clear from some of the more recent policy analyses that Portugal should see the promotion of industry-academic relations as a key factor in the development of their National System of Innovation. Portugal’s Ministry of Science, Technology, and Higher Education (MCTES) acknowledges that Portugal’s HEIs need to be more attuned to the social and economic needs of the market and society (MCTES 2006). As the Portuguese economy modernizes, its labor needs will change, and the country’s higher education system should be prepared to respond to these changing needs. The education system should accommodate the

expanding needs for skilled workers across a wider range of occupations. As the OECD's evaluation observed, these changes may involve further differentiation between the systematic roles of polytechnics and universities. In defining these roles, it is important that policy makers understand the differences between universities and polytechnics – not just in their curricula, but in their geographical structure and their interactions with industry. In addition, the enrollment figures in Portugal's HEIs have been turbulent lately. The total number of higher education enrollments in Portugal doubled over the period 1990-2002, and then dropped by 10% in the period 2002-2006. Future restructuring may involve the consolidation or closing of several institutions. Policy makers should try to understand the consequences that these decisions may have on local industry.

1.2 Thesis Objectives

As outlined above, the Portuguese government is paying increased attention to the development of their NSI and the role that higher education plays within it. As the Portuguese government considers new policies which could shape the geographic distribution of its higher education system, it is important to understand the potential consequences of these policy actions within the NSI as a whole. Policies that impact Portugal's higher education system may have subtle effects on the geographic distribution of its institutions relative to the industries with which they interact. The goal of this thesis is to explore how the geographic distribution of both sides of the binary Portuguese higher education system corresponds with the geographic distribution of Portuguese industry and its innovation-creating potential. As a comparative baseline for analytical purposes, locational correlations in two U.S. states (Georgia and Pennsylvania) are also developed in this thesis.

The contribution of this thesis is its examination of both universities *and* university alternatives. The literature until now has focused heavily on the innovation effects of universities and has neglected the impacts that university alternatives have on innovation creation. This thesis will compare the effects of universities and university alternatives across the two different educational systems in Portugal and the U.S. In discussing the background for this work, I will distinguish between the "multipurpose" US system and the "binary" Portuguese system. Additionally, this thesis incorporates the production of human capital as an input to innovation. Newly available data sources publish the number of graduates from different courses of study

and my analysis includes these graduate figures in a production function that describes innovation creation.

The purpose of this thesis is twofold. I would first like to inform policy makers in Portugal and elsewhere of the potential impact of higher educational structures on NSI functionality. Secondly, I would like to examine the geographic effects of higher education institutions and contrast the effects of universities and university alternatives in Portugal and the U.S. As a whole, the results of this analysis should inform policy makers who seek to reform or expand their higher education systems.

The answer to the question of how locational effects impact innovation could provide guidance for locating new schools within the country or for the consolidation of older schools (i.e. at which locations should schools consolidate?). This should be particularly interesting to Portuguese higher education administrators, since Portuguese schools have recently begun consolidation due to lower enrollments and higher institutional costs. If the analysis uncovers strong locational trends, then the results could provide some guidance to administrators as they decide where new or consolidated schools should be located. The results should be relevant as well to economic ministers who wish to guide the formation of industry clusters. The conclusions of this study may also be generally applicable in developing countries, whose higher education systems are not yet fully fledged. The specifics of each chapter are outlined below.

1.3 Thesis Outline

The next two chapters of this thesis give an in-depth look at the literature and the historical background on which this thesis will build. Chapter 2 discusses economic theory and reviews the literature regarding how to quantify the interactions between higher education and national systems of innovation. Chapter 3 examines the Portuguese and U.S. higher education systems in and how they fit into the theory introduced in Chapter 2.

The objective of Chapter 2 is to provide the reader with the economic framework that underpins our current ideas about innovation, as well as to provide an overview of the metrics used in studies of innovation. It summarizes the evolution of theory regarding how economic growth is created and it emphasizes the key revelations that have driven the economic theory forward.

Chapter 2 then presents the theory of National Systems of Innovation (NSI), which describes the interaction between all of the institutions and players that contribute to a nation's 'innovation potential'. In Chapter 2, I describe the methods that have been employed to describe NSIs and to measure the effects of higher education institutions within them. There are several different approaches to innovation measurement: researchers of innovation have used several different techniques to describe how innovations are created and disseminated. The analysis techniques in the literature have evolved over time as new data sets and computational power have become available. Chapter 2 summarizes the findings in the literature and discusses the current state-of-the-art in geographic studies of innovation.

The purpose of Chapter 3 is to describe the higher education systems in Portugal and the U.S. and to examine how these systems fit into the overall NSI in both countries. Higher education systems are a key component of NSIs and are the focus area of this thesis. In addition to universities, higher education systems include "university alternatives", such as polytechnics and community colleges. The available university alternatives are fairly different in Portugal and the U.S. and, in turn, these alternatives play different roles in the NSIs of the two countries. Chapter 3 draws comparisons between the higher education systems in Portugal and the United States and discusses recent trends in education in both countries.

The following two chapters present the analytical methodology and results that comprise the quantitative portion of this thesis. Chapter 4 describes the method that is used (1) to compute regional concentrations for industry and education and (2) to identify where industry and higher education are geographically co-located. Chapter 4 then defines the innovation production function (based on the literature reviewed in Chapter 2) that is used in an econometric analysis. The production function is used to determine the correlation between the independent variables of education-industry co-location, research spending, and other regional characteristics; and the dependent variable of industrial innovations (as measured by industry surveys). Chapter 4 also describes the data sources used for the analysis, the method of harmonizing U.S. and Portuguese data, and the inherent limitations of the selected methodology.

Chapter 5 presents the results of the analysis. The co-location analysis results are presented first, with tables and maps showing in which sub-regions co-locations exist. These co-location results

are compared for the different regions and I discuss some cultural factors that may contribute to the results. Then the econometric results are presented. These results show what effect the education-industry co-locations had when they were introduced into the innovation production function.

Chapter 6 presents the conclusions that may be drawn from the analysis and frames the results of the analysis in a policy context. The thesis concludes with recommendations for further study.

2 Economic Theory and National Systems of Innovation

The introduction highlighted Portugal's interest in stimulating economic growth and the recent attention they have given to policy geared towards creating innovation. This chapter introduces the neoclassical economic theory that underpins our focus on innovation as a driver of economic growth. In this chapter, I present the concept of National Systems of Innovation (NSI) and then review attempts in the literature to quantitatively measure innovation systems and innovation output in general. This review shows that higher education and the development of human capital are common themes in the NSI literature, but that newer methods of innovation measurement are more survey-based. Then, knowledge spillovers are discussed as a tangible side effect of functioning NSIs and literature pertaining to knowledge spillovers is reviewed.

2.1 Economic Growth through Innovation

In the realm of economic theory and empirical research, endogenous growth models have demonstrated the contribution of knowledge accumulation and technological advancement to economic growth. Classical economic theorists believed that a nation's productivity was determined by the interaction of two factors: capital and labor. In the mid-twentieth century, economists observed that there is a quantifiable element of growth, which they termed "total factor productivity" (TFP), that is not accounted for by labor and capital alone. Neoclassical economic theory states that the portion of output derived from TFP is driven by productivity-enhancing improvements in technology. The current belief is that these technological improvements are rooted in innovation – both the innovation of products and of processes. Neoclassical economists believe that technological advancement through "innovation" is a way for countries to develop their economies (Solow 1957) (Romer 1986).

With the premise that innovation leads to economic growth, the question to answer is: "Where should countries invest their resources for the purpose of creating innovation?" Economic theory has not converged on a one-size-fits-all answer to this question. That is, there is no single investment that guarantees success. Instead, Nelson has advanced the idea of National Systems of Innovation (NSIs), which are composed of all the separate institutions that contribute to knowledge creation. Nelson argues that a fully functioning NSI has a balance of entities that are together capable of creating, transferring, and commercializing knowledge (Nelson and Rosenberg 1993). The visual notion of a triple-helix that represents the symbiotic relations tying

together the elements (government, universities, businesses) in a NSI has acquired wide currency (Etzkovitz and Leydesdorff 2000). This focus on innovation and institutional interaction is the reason that organizations tracking innovation focus heavily on R&D spending and the interaction between research institutions and industry.

Since economic theory views NSI functionality as important to economic growth, we would like to be able to measure it. The following section will discuss attempts to quantify and assess a country's NSI. The survey in Section 2.2 will show that different organizations have different perceptions concerning which factors matter for innovation. In spite of those differences, innovation measuring organizations generally agree with the belief that National Systems of Innovation are strengthened when the systems' disparate parts connect with each other and interact. That is to say that interaction between the separate domains of academia, industry, and government is believed to promote innovation potential. This takeaway has important implications for the analysis in Sections 4 and 5, which will estimate the co-location between higher education and industry in Portugal and the U.S.

2.2 Measuring Innovation

One obstacle to economic studies of innovation is the lack of a direct measure of innovation output. Technological innovation is a multi-dimensional and complex concept and is impossible to measure with a single, un-biased index. The results of innovation are varied, from new products and services to new methods of production and delivery. Because of the variety of innovation outputs, there is no single-dimensional measure that can capture "innovation output". Nevertheless, economists need some sort of yardstick to measure and compare progress and to inform policy development. To this end, innovation indicators are often used to quantify different aspects of the innovation process. Innovation indicators include a mixture of measures, from inputs to innovation (such as R&D spending and human capital development) to outputs of innovation (such as new products, patents, and scientific publications). Our use of innovation indicators has changed over time as our understanding of the process of innovation has developed.

When technological innovation became an economic focus in the 1960s and 1970s, innovation was perceived as being a linear process. It was believed that "basic" research produced new

scientific knowledge, then “applied” research found a practical use for that knowledge, and product development implemented the knowledge in a marketable form as an “innovation”. According to this linear model, innovation should result directly from R&D spending. However, the linear model was found to be flawed when researchers observed that some innovations occur independently of R&D. In fact, many firms that produce innovative products and services do not have any R&D activity. These firms may rely, for instance, on licensing other firms’ innovations or on acquiring human capital in possession of innovative ideas. Innovating firms may get new perspectives or ideas from interactions with their suppliers and customers, or they may base their innovations on their competitors’ products. Additionally, some stages of the linear research model may be sidestepped by accessing knowledge from public sources (such as journal publications) or by hiring consultants. In short, a firm looking to innovate has many sources of knowledge besides in-house R&D. The linear model of innovation does not account for interactions between firms and with other knowledge-creating institutions and, furthermore, it only accounts for *inputs* to the innovation process (Hansen 1999).

In the 1980s, innovation research shifted away from measuring innovation inputs and towards measuring innovation *outputs*. Many studies began to use patenting activity as a proxy for innovative output. Patent statistics are convenient because patents are accessible and they are geographically and temporally labeled. The number of patents has been used as an innovation output in several studies examining the effects of knowledge spillovers on innovation production (Jaffe 1989). Jaffe (1989) found a significant knowledge spillover effect of university research on corporate patenting activity. However, it is well-known that patents have several flaws as innovation indicators. The reliability of patent data is questioned because not all patented innovations prove to be commercially-viable innovations, and many successful innovations are never patented (Mansfield 1984; Griliches 1990). Furthermore, inventions are not necessarily patented since firms can appropriate returns to innovative investment by other means (Levin, Klevorick et al. 1987). There is also an argument that patent data should be viewed as an *input* measure to innovation rather than an output. The argument is grounded in the fact that it is not the number of patents issued that matters, but how effectively those patents are utilized to create a finished product or service.

In the 1990s, innovation researchers began to treat innovation as an interactive process with different phases and sources of technological change. Recognizing the limitations of the linear and patent-focused models of innovation, statistical organizations have turned to collections of innovation indicators and to industry surveys in their attempts to quantify innovation. The innovation measurement models described below present a more well-rounded picture of the innovation process by looking at multiple facets of the knowledge economy.

2.2.1 Innovation Performance Indicators

To measure and compare the innovation performance of different regions, observing organizations often compile a number of statistical indicators that provide a snapshot of regional innovative activity. This sub-section presents one such collection of indicators from PRO INNO Europe (formerly CORDIS), a European Commission entity which seeks to document how European countries progress in innovation. The different axes of the radar plot in Figure 1 represent indices created by PRO INNO Europe (2008). The indicators that are included in these indices are listed in Table 1 on the following page; PRO INNO normalized and averaged the indicators to derive their individual indices. Figure 1 compares Portugal's innovation performance to the average performance of the 27 countries in the European Union (as of 2007). According to Figure 1, Portugal's performance is about average for Innovation & Entrepreneurship, but the other indicators are lower than average because of Portugal's low rates of education, R&D spending, and intellectual property generation. This largely indicates a lack of sustained investment in different elements of the Portuguese knowledge economy.

Figure 1. Innovation Indicators: European Innovation Scoreboard, Portugal (2007)

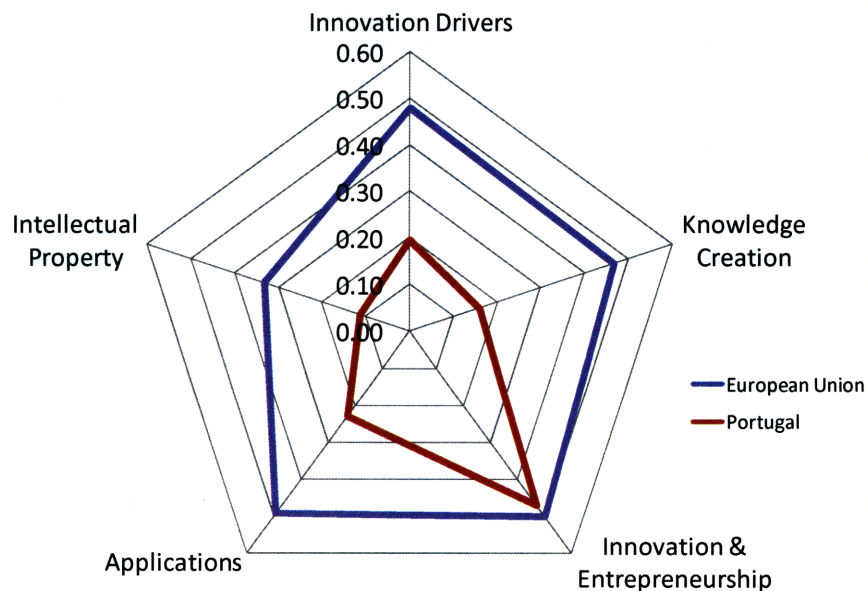


Table 1. Innovation Indicators in PRO INNO's European Innovation Scoreboard 2007

Innovation drivers	Innovation & entrepreneurship
Science & Engineering graduates	SMEs innovating in-house
Percent of Population with tertiary education	Innovative SMEs co-operating with others
Broadband penetration rate	Innovation & Information Technology expenditure
Participation in life-long learning	Early-stage venture capital
Youth education attainment level	Organizational innovation
Knowledge creation	Applications
Public and Business R&D expenditures	Employment in high-tech services
Share of medium-high and high-tech R&D	Exports of high technology products
Enterprises receiving public funding	Sales new-to-market and new-to-firm products
Intellectual property	Medium-high / high-tech manufacturing employment
EPO, USPTO, and Triadic patents	
Community trademarks and designs	

2.2.2 Innovation Indicator Survey

This sub-section presents a survey of different organizations that observe innovation activity. The surveyed organizations are PRO INNO Europe, EUROSTAT, the Organization for Economic Co-operation and Development (OECD) and the World Bank. These organizations were selected because they have each generated public reports of innovation measurements. In conducting this survey, I examined reports published by the four organizations. Since 2001, PRO INNO Europe has published an annual European Innovation Scoreboard report (PRO-INNO Europe 2008), which attempts to benchmark the innovation performance of European Union member states. EUROSTAT has published several books of innovation indicators; the latest to date is *Science, Technology and Innovation in Europe 2008* (Eurostat 2008). The OECD has its own scoreboard of science and technology indicators; the latest in this series is the *OECD Science, Technology, and Industry Scoreboard: 2007* (OECD 2007). The indicators of interest for the World Bank are taken from a World Bank report which describes the ideal measurements for benchmarking a national innovation system (de Ferranti 2003).

The results of my survey of innovation indicator reports are presented in Table 2 on the following page. Table 2 delineates the degree to which each organization included different factors in assessing a nation's innovation capacity. These results are not exhaustive, but their presentation highlights commonalities and differences in how the surveyed organizations perceive the importance of different indicators in innovation measurement. Some observations from this survey are presented on the page following the table.

Table 2. Survey of Statistics Included by Innovation-Measuring Organizations

○ = Not included, ⊙ = Included as an indirect factor, ● = Included as a direct factor

Innovation-Related Inputs	PRO INNO	EUROSTAT	OECD	World Bank
Average education attained	⊙	⊙	○	●
Tertiary education attainment	●	●	●	⊙
Education enrollment	○	●	⊙	●
Science/technical personnel (% of pop.)	●	●	●	●
Worker training (share of firms that train)	⊙	○	○	●
Participation in lifelong learning	●	○	○	⊙
Public R&D expenditure	●	●	●	●
Private R&D expenditure	●	●	●	⊙
University R&D financed by business	●	⊙	●	●
Perceived quality of R&D institutions	○	○	○	●
Tax treatment of R&D	○	○	●	●
Foreign direct investment flows	○	○	●	○
Functioning of NSI				
Productivity growth (TFP)	○	⊙	●	●
Patents received (USPTO, EPO)	●	●	●	●
Articles published	○	○	●	●
Promotion of technology transfer	○	○	⊙	●
Geographic concentration of patents	○	○	●	○
Exports of high-tech products	●	●	●	○
Employment in high-tech manufacturing	●	●	⊙	○
Employment in high-tech services	●	●	⊙	○
Share of high-tech R&D	●	●	⊙	○
Early-stage venture capital	●	●	●	●
Public funds for enterprise innovation	●	○	○	⊙
SMEs innovating in-house	●	○	●	⊙
Innovative SMEs co-operating with others	●	○	●	⊙
Sales of new products	●	○	○	○
Extended NSI				
ICT Investment	●	●	●	●
Internet connectivity	●	⊙	●	●
Computers per capita	○	○	⊙	●
Telecommunication regulations	○	○	●	●
Share of students interning in industry	○	○	○	●
Tertiary education workers studying abroad	○	○	●	●
Research agreements with foreign universities	○	○	○	●
Foreign students in tertiary education	○	●	●	●
Researchers in higher ed. moving to industry	○	⊙	●	●
Researcher mobility among firms	○	●	○	●

Below are some observations from the survey of innovation indicators in Table 2:

- Several innovation measures are included by all four organizations: tertiary education attainment, public and private R&D expenditure, venture capital investment, and investment in information and communication technology (ICT).
- The World Bank is unique because it uses qualitative measures to account for the promotion of technology transfer. The World Bank also includes measures of education quality (such as test scores) and R&D institutional quality.
- PRO INNO emphasizes efforts in education and small and medium enterprise (SME) innovation but does not account for much knowledge sharing between academia and industry.
- PRO INNO and the World Bank were explicit in categorizing innovation factors as “inputs” (such as education and R&D) or “outputs” (such as the number of patents filed)
- In addition to static measurements, EUROSTAT provides measurements of growth in R&D spending, education, and science/technology personnel to track which countries have dynamic investment and employment patterns.
- Both the World Bank and OECD measure mobility of researchers both from higher education towards industry and foreign countries. They both place value on knowledge and personnel transfer across national borders.

Perhaps the most important take away from this survey is that organizations do not often agree on which metrics to use in describing a national system of innovation¹. Many researchers have thus turned from using a battery of statistical indicators and have begun using targeted industry surveys instead.

2.2.3 Industry Surveys

A recent trend in innovation measurement is the use of surveys of innovation outputs. Evangelista (1997) compares the scope of these innovation surveys and categorizes them into two types: those that collect information on the innovations introduced, hence concentrating on the products of innovative activity; and those that question firms about input, output and the nature of the innovative process, hence focusing analysis on the subjects of innovative activity (Evangelista, Perani et al. 1997). This section will describe an innovation survey conducted by

¹ And, with limited resources for collection, evaluation, and reporting; organizations cannot consume every metric that is available.

the U.S. Small Business Administration which measured the objects of innovation activity. Then it will examine the Community Innovation Survey (CIS) and the Georgia Manufacturing Survey (GMS), which focus on the subject of innovative activity.

In 1982, the United States Small Business Association (SBA) conducted a census of innovation citations from over 100 scientific and trade journals. The SBA census is an example of what has been termed Literature Based Innovation Output (LBIO) measurement. In contrast to the patent data discussed in Section 2.2, this LBIO data is compiled by screening specialist trade journals for announcements of the market introduction of commercially-viable products. The SBA defines an innovation as “a process that begins with an invention, proceeds with the development of the invention, and results in the introduction of a new product, process, or service to the marketplace” (Ács and Audretsch 1990). The survey results were classified by industry codes and geography, and they provided researchers with a snapshot of innovative activity in 1982. Feldman (1994) used the survey results to map the spatial patterns of innovation in the U.S. and concluded that commercial innovation in the U.S. benefits from spillovers from the technological infrastructure, as modeled by R&D spending, geographic industry concentration (Feldman 1994). LBIO data has several advantages over patent data. First, it is a direct measure of innovation (i.e. market introduction). Second, the LBIO indicator includes innovations that do not have patent protection. There are downsides to surveys based on trade journals, though. Not all firms are equally likely to announce new products. Even within the same firm, not all product lines have equal likelihood of publicity. Because of these flaws, van der Panne (2007) concluded that the eligibility of LBIO data for innovation research remains controversial (Van der Panne 2007). In addition, the 1982 SBA survey data is now somewhat obsolete, and no trade journal survey of this scope has been conducted in recent years.

In the late 1990s, the European Community sought to design a standardized innovation questionnaire that would be routinely administered to firms in all EU countries. The project, titled the Community Innovation Survey (CIS), was a joint venture between Eurostat and the SPRINT/European Innovation Modeling System program. The CIS is a comprehensive survey that attempts to measure both inputs and outputs to innovation and its methodology is based on the guidelines for the collection of innovation data laid out in the 1992 *Oslo Manual* (OECD Statistical Office of the European Communities 2005). The first Community Innovation Survey

(CIS1) was conducted in 1992 and it was notably the first attempt to draft innovation indicator data that would apply to *both* service and manufacturing industries (Hansen 1999). Eurostat revised the questionnaire after CIS1 and subsequent surveys took place in 1996 (CIS2), 2001 (CIS3), and 2004 (CIS4). The CIS covers firms in all EU member countries and its questions focus on firms' innovation expenditures, partnerships for innovation, and their sources of information relating to innovative activities. CIS data has advantages over patent statistics in that the survey asks firms if they have introduced innovations that are new to their firm and/or new to the market. In this sense, it should capture innovations that were not patented and should not include patents for inventions that were never marketed. There are, however, also some disadvantages to the CIS methodology. Although the CIS questionnaire contains a detailed definition of what comprises a product or service "innovation", CIS survey results reflect the subjective views of the firms that are surveyed, whose managers have to decide what they regard as a product/service innovation. This mis-categorization leads to some error in the aggregated survey results.

Though some non-European OECD countries have begun to adopt the CIS methodology, there has been no nationwide innovation survey in the U.S. Most U.S. surveys take place at the state level and are focused on business or economic development concerns. In 1994, the Georgia Institute of Technology began conducting the Georgia Manufacturing Survey (GMS), a state-wide innovation survey of Georgia businesses. The GMS is a study conducted every two to three years by Georgia Tech's office of Economic Development and Technology Ventures and the Georgia Tech School of Public Policy, to assess the business and technological conditions of Georgia's manufacturers (Youtie, Shapira et al. 2005). Many of the questions in the GMS are worded to enable benchmarking of GMS results with the CIS. Because of its methodological similarity with the CIS, the GMS shares the same advantages and disadvantages, which are listed in the preceding paragraph. CIS4 and GMS results for Portugal and Georgia are used in the analysis in this thesis and are they discussed further in Section 4.2.3.

To summarize the progress in innovation measurement, I observed that researchers began measuring innovation in the 1960s, following a linear framework that focused on R&D inputs to innovation. In the 1980s, the use of patent data as a proxy for innovation outputs became popular, and this approach still persists today. However, organizations measuring innovation

have branched out beyond patents to measure all quantifiable aspects of national systems of innovation. My survey of four innovation-measuring organizations demonstrated that the collections of statistical indicators can vary depending on the organization gathering the statistics and, to date, no harmonized “innovation index” has been widely accepted. Instead, researchers have turned to the direct measurement of innovation outcomes using business surveys, such as the CIS and the GMS discussed above. Measurements of innovation potential typically focus on the creation and use of knowledge by institutions in the innovation system. The following section will discuss the exchange (both intentional and unintentional) of knowledge between institutions in a national system of innovation. Knowledge is often transmitted through a process known as “knowledge spillover”.

2.3 Knowledge Spillovers

Knowledge spillovers occur when knowledge created by one firm or institution is disseminated and adopted by other firms. Several practical ways in which knowledge spillovers occur between firms in an industry are: industry conferences and seminars, workers within an industry changing employers or starting their own business, and industry consultants applying similar techniques to different firms. New knowledge usually contains “tacit” elements, or elements that cannot be codified or transferred in media form. In other words, researchers believe that the transfer of tacit knowledge involves face-to-face contact or hands-on interaction (Amsden 2001). Thus, there is a locational aspect to knowledge spillovers, and many researchers have observed that the knowledge spillovers diminish with distance. This is one common explanation for why firms in similar industries tend to cluster.

Knowledge spillovers are not limited to intra-industry interaction, though. Knowledge created at research and higher education institutions can also spillover into the industrial sector. These spillovers may occur through: university spinoffs, faculty who consult with industry, and students who take internships with firms or who have their research sponsored by industry. Several studies claim that industrial firms tend to locate near universities for the same reasons that motivate industrial clusters: the availability of human capital and the potential for knowledge spillovers. Typical approaches to measuring spillovers from higher education have focused solely on the research activities at universities. However, I argue that non-university and non-research institutions play an important (and possibly undervalued) role in national

innovation systems as well. The following section reviews literature pertaining to knowledge spillovers.

2.4 Literature Review

This section will discuss how this field of study has developed since the introduction of the knowledge production function in 1979. Over time, the standardization of innovation data collection has enabled researchers to move from local, case study based work to cross-regional comparisons. Additionally, the expansion of data collection efforts has enabled researchers to look at finer geographic resolutions. Feldman (2000) and Varga (1998) each review a substantial body of work and find that academic knowledge spillovers are geographically mediated and have a positive effect on innovative output. (Varga 1998; Feldman 2000). However, it is important to note that few of these studies have examined the difference between universities and university alternatives (i.e. community colleges, polytechnics), and no literature was found that modeled the location effects of university alternatives on industrial innovation. This thesis attempts to open this niche for exploration.

2.4.1 Knowledge Spillovers and the Knowledge Production Function

The most appropriate model in the literature for studying the effects of higher education on regional high technology industry is the Griliches-Jaffe knowledge production framework (Varga 1998). Griliches (1979) used a knowledge production function (KPF) in the form of the Cobb-Douglas equation to model the innovation process with patent applications as an output resulting from R&D inputs (Griliches 1979). This framework was first applied to model university effects on innovation activity by Jaffe (1989), who used patents as a proxy for innovative output and found a strong regional correlation between university R&D and innovation creation (Jaffe 1989). Jaffe finds that for each U.S state, the number of patents by businesses is positively correlated with the R&D expenditure of universities located in the same state. Based on this finding, Jaffe infers that there *may* be knowledge spillovers from universities to businesses.

Recognizing the limitations of the patent measurement proxy, researchers made extensive use of the Small Business Innovation Database described in Section 2.2.3. Acs et al. (1992) and Feldman (1994) use the Griliches-Jaffe KPF with the SBA's innovation count data as a measure of innovative output. They find the same fundamental result: that increased R&D inputs

correlate with increased innovation (Feldman 1994). Audretsch and Feldman (1994) also conclude that higher levels of university research correlate with innovative activity (Audretsch and Feldman 1994). The Small Business Innovation Database was perceived in the literature as a valuable alternative to patent statistics, but the fact that the database was only collected for one year prevented its use in any long term studies.

Several studies found that proximity to potential partners such as suppliers, customers, universities, R&D and financial institutions significantly and positively influences innovation (MacPherson 1998) (Romijn and Albaladejo 2002) (Uzun 2001). Other work has examined the influence of university research on industrial innovation. These studies (GUIRR (Government University Industry Research Roundtable) 1991) (Mansfield 1991) (Cohen, Nelson et al. 2002) emphasized the inter-industry differences in the relationship between university and industrial innovation. Their consensus is that the biomedical and pharmaceutical sectors are unique in that advances in university research affect industrial innovation more significantly and directly in these fields than in other sectors. More recent work has added a spatial element to the KPF to model the geographic extent of knowledge spillovers. Fischer (2003) found that knowledge spillover effects transcend political boundaries in Austria (Fischer and Varga 2003). Moreno (2005) found distance decay in the effect of R&D on patenting in Europe (Moreno, Paci et al. 2005).

The econometric use of CIS results has gradually increased since the survey was introduced in 1992. Most of the early CIS literature focused on fine-tuning and harmonizing the survey for later iterations. Smith (2005) catalogues the econometric studies performed with CIS data. He notes that the researchers are growing to accept the data source and that “formal evaluations of CIS as well as data tests by researchers have been broadly positive to the quality of the data flowing from the survey.” (Smith 2005).

2.4.2 University-Industry Interaction

Several studies have looked at the characteristics of higher education institutions that correlate with university-industry interaction. However, owing to the lack of a standardized measure for academic-industry interaction, these studies are largely survey-based, with results that are limited to the geographies in which they were administered. These studies show mixed results on the

effects of HEI “prestige” and the amount of industry collaboration. In a survey of universities and industries, Mora-Valentin et al. (2004) find correlation between the perceived reputation of research organizations (mostly universities) and the perceived success of cooperative industry agreements. In other words, businesses believe that working with reputable HEIs leads to successful outcomes (Mora-Valentin, Montoro-Sanchez et al. 2004). In terms of institutional attitudes towards industry engagement, Lee’s (1996) survey of 1,000 U.S. university faculty found that faculty in applied disciplines (in this case, chemical engineering, electrical engineering, computer science, and materials science) are much more supportive of technology transfer initiatives than their colleagues in the basic or social sciences.

To summarize, economic theory shifted in the second half of the twentieth century towards a focus on technological advancement and knowledge creation as means for economic development. Current theory states that innovation and technological advancement are not chiefly derived from industrial research activity, but that academic and government institutions also play a role in countries’ national systems of innovation. As theories evolved about how innovations are created and disseminated, the metrics used to measure innovation also evolved. Innovation analysis has grown from simple R&D measurements to a whole battery of innovation indicators that are used to measure the size and functionality of national systems of innovation. The consensus in the innovation systems literature is that geographic proximity to universities’ and research institutions correlates with innovation output. The literature is limited, though, in that it does not examine the effects of non-university higher education on innovation output. Also, most studies are limited in their geographic scope: few studies compare the effects of HEIs on innovation output across different countries. This thesis addresses both of these limitations. It will compare the higher education systems in the U.S. and Portugal and then examine how the systems’ geographic distributions and courses of study correlate with industrial innovation output.

3 Higher Education Systems in Portugal and the U.S.

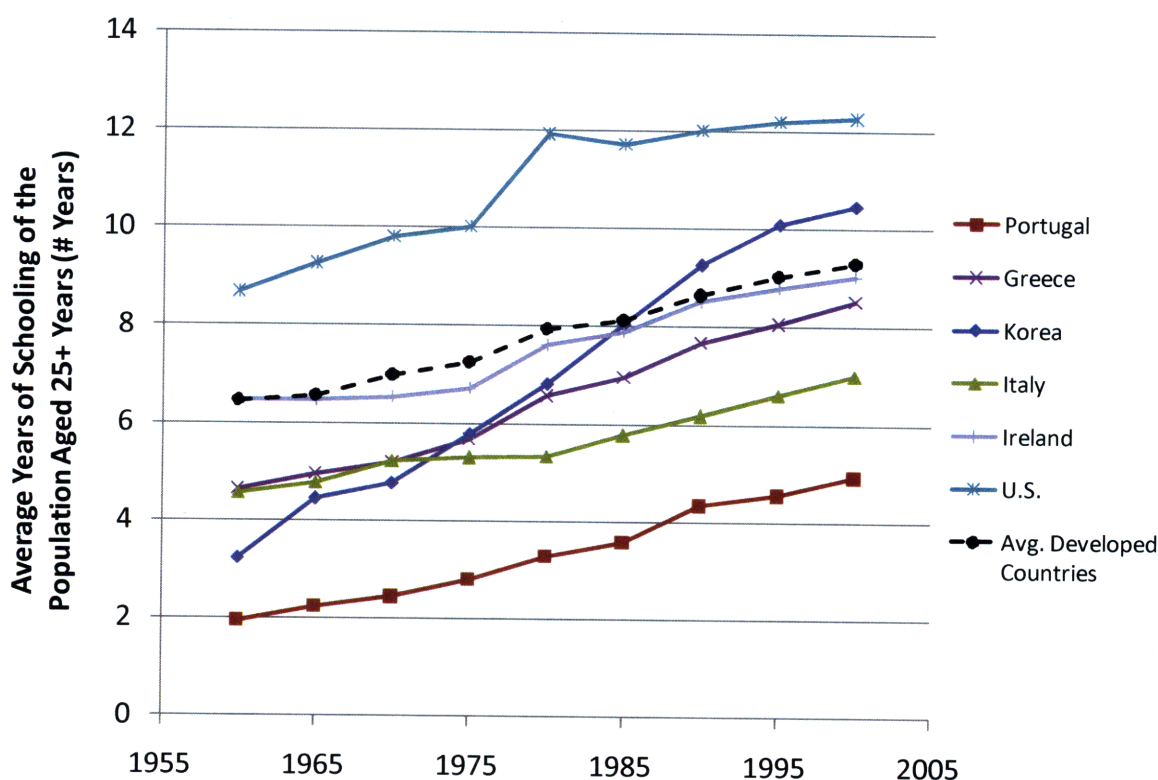
This chapter describes the development and structure of the higher education systems in both Portugal and the United States. A primary focus of this chapter is to delineate the differences between universities and “university alternatives” in the two countries. For the purpose of this discussion, the term “university alternatives” refers to any non-university institutions of post-secondary schooling. This term includes community and technical colleges, vocational schools, and polytechnic institutions (the widely used term in Portugal). In this chapter, I will introduce the distinction between the “binary” system in Portugal and the “multipurpose” system in the U.S. The two systems differ in how the roles of their university alternatives are defined and interpreted. The chapter will present the growth rates of higher education in both countries and will discuss drivers behind those rates. It will look at the policy drivers and economic goals that motivate the current system structures. The descriptions herein draw from internal assessments by researchers in both countries and from external evaluations by such organizations as the OECD and UNESCO. After I present the educational systems from both countries, I contrast the two systems and highlight their relative strengths and weaknesses.

3.1 Comparison of Historical Education Levels

For the Portuguese population, the average years of schooling of the working age population is low compared to the country’s European and OECD peers. The country’s average schooling has increased since the 1960s, but Portugal has not kept pace with other developed countries that came from behind (like Spain, Korea, Ireland Italy, and Greece). Korea, for one, created a huge increase in its population’s education level through targeted investments and strict education policies. Ireland, for another, grew its education sector by reinvesting the spoils of its economic development policies into education.

In spite of the massive expansion of the Portuguese higher education sector, overall education levels of the population are below the level of countries with which Portugal compares itself (OECD 2007). The U.S. has working age schooling levels that are above the average for developed nations. This strong lead results from education investments that the U.S. made prior to the 1960s. Figure 2 below charts the average education attainment of the working age population in these countries, as well as the average for developed countries, over the past fifty years.

Figure 2. Historical Educational Attainment of Portugal and its Peers²



The United Nations Education, Scientific, and Cultural Organization (UNESCO) publishes a different educational statistic called the ‘School Life Expectancy’. This measure estimates the years of education that the average school-age child *today* can expect to receive, based on the current enrolment at each level of education. Portugal is more competitive in the forward-looking “School Life Expectancy” than it is in the backward-looking “Educational Attainment” indicator. As of 2006, the School Life Expectancy is 15.2 years in Portugal and is 15.7 years in the U.S. These figures are just shy of the OECD average of 15.9 years (UNESCO Institute for Statistics 2008). In essence, school age students in Portugal today can expect to receive an amount of schooling comparable to that of their European and OECD peers. This “School Life Expectancy” indicator captures the effects that the higher education expansion and new education policies in Portugal are expected to have on current students³. However, the comparison of the two indicators does show that Portugal came rather late to investments in education relative to their peers. The following sections will take a more detailed look at the higher education systems in Portugal and the U.S.

² Barro, R. J. and J.-W. Lee (2000). International Data on Educational Attainment: Updates and Implications. *CID Working Papers*. Cambridge, MA, Harvard University, Center for International Development.

³ The “School Life Expectancy” indicator measures the amount of time that current school-age students are expected to participate in school; the indicator does not offer any measure of educational curriculum or quality.

3.2 Portugal's Higher Education System

The higher education system in Portugal has changed significantly in the past 40 years. The changes started with the education access reforms of the 1970s and continued with the creation and expansion of the polytechnic and private education sectors. Higher education continues to receive attention today because of the Portuguese government's concern for creating a modern workforce and their desire to increase the educational attainment of the population. This section will describe the structure and development of the Portuguese system of higher education.

3.2.1 Structure

Portuguese higher education policy is regulated by the Education Act of 1986 and is the responsibility of the Ministry for Science and Higher Education. The Portuguese higher education system is a “binary” system that includes universities and polytechnic institutes (both the university and polytechnic sectors encompass public and private institutions). Entrance to higher education is based on passage of an upper-secondary course (or legal equivalent), on entrance examinations, and on other pre-requisites. The Portuguese system includes 175 institutions that are distributed as shown in Table 3 below.

Table 3. The Breakdown of Higher Education Institutions in Portugal ⁴

Sub-Systems of Higher Education	Type of Institution	Number of Institutions
Universities	Public	15 ^a
	Private	49
Polytechnics	Public	33
	Private	68
Other		8
TOTAL		175

^a Two public universities (Aveiro and Algarve) include polytechnic schools

Portuguese higher education offers the following academic qualifications: First-degree (*licenciado*), Master's degree (*mestre*), and PhD (*doutor*). University and Polytechnic institutions confer First-degrees and Master's degrees, but only universities confer doctoral degrees. The missions of the university and polytechnic institutions are quoted below:

“University education aims to ensure solid scientific and cultural preparation plus technical training that qualifies students for professional and cultural life while developing the capacity to innovate and make critical analysis.” (EURYDICE 2007)

⁴ Ferreira, J. B., M. d. L. Machado, et al. (2008). The Polytechnic Higher Education Sector in Portugal. Non-University Higher Education in Europe. J. S. Taylor, Springer Netherlands. **23**: 191-214.

“Polytechnic education aims to ensure solid scientific and cultural preparation plus technical training, developing the capacity to innovate and make critical analysis and transmit scientific knowledge that is both theoretical and practical in order to prepare students for professional life.”
(EURYDICE 2007)

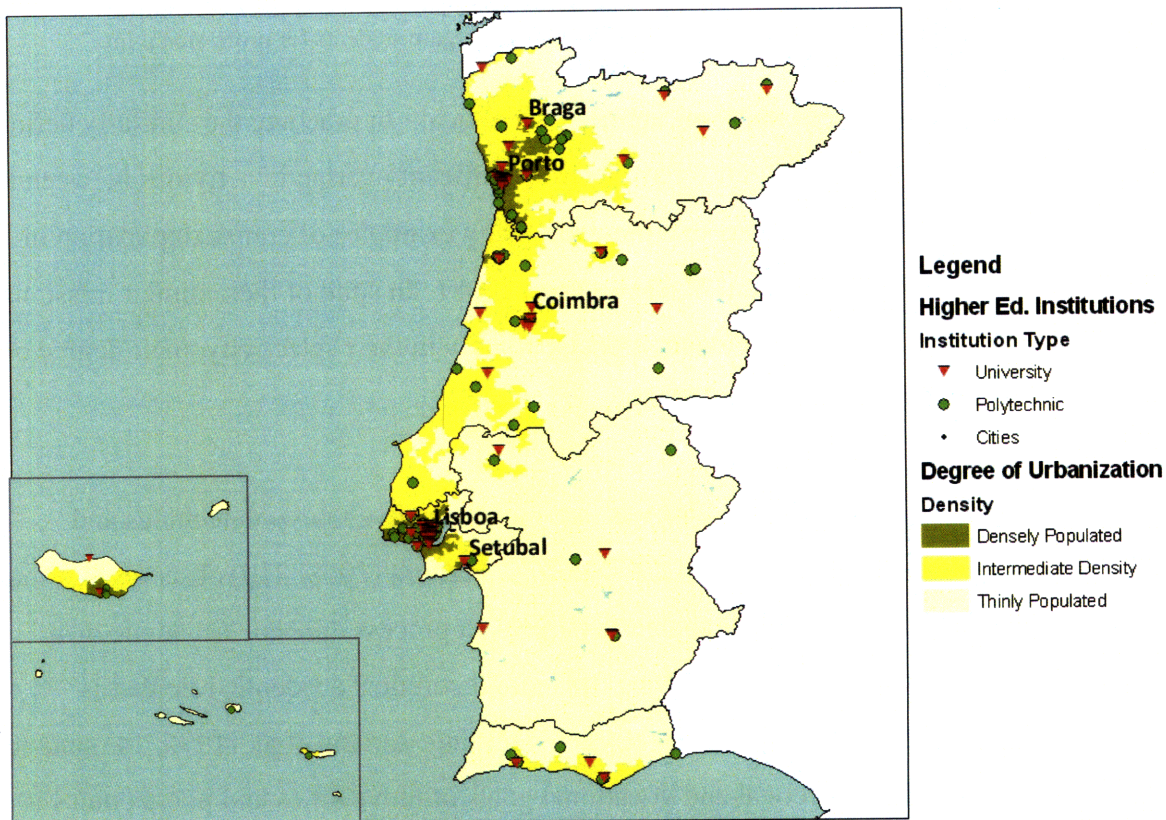
The reader should note that these missions are nearly identical. In practice, the similarly defined missions of universities and polytechnics have led to significant overlap in activities between the two institutional types. Ferreira claims that there are many examples of course duplication in universities and polytechnics (Ferreira, Machado et al. 2008). In spite of their similar missions, universities and polytechnics differ in many aspects, notably in their selectivity, their degree of institutional autonomy, and their regional focus.

According to the OECD, universities in Portugal are more selective than polytechnics and generally provide better quality teaching (OECD 2007). Ferreira (2008: 210) observes that many polytechnics have attempted to emulate the universities in a process dubbed “academic drift,” wherein the polytechnics “drift” towards filling the more theoretical academic role that is traditionally reserved for universities. Supporting this finding, Amaral et al. (1996: 14) state that the distinction between the theoretical and vocational goals of universities and polytechnics is “more formal than real”. To a degree, it appears that the two sectors (university and polytechnic) are meeting in the middle, as some polytechnics try to offer the same programs as universities and some universities begin to offer vocational courses.

In terms of institutional autonomy, the Education Act of 1986 provides universities in Portugal with scientific, pedagogic, cultural, administrative, financial, patrimonial, and disciplinary autonomy. The autonomy of polytechnic institutions is more limited than that of universities, though. Polytechnics do not have the freedom to organize their curricular offerings; any course and curriculum changes must be approved by the Minister of Education. Additionally, polytechnics have less financial and administrative flexibility than universities. It is perhaps because of this limited autonomy, or because of the perception of being low-quality, that many polytechnics designed strategies in the late 1980s and early 1990s that would enable them to eventually *become* universities.

When polytechnics were introduced, one of the objectives for polytechnic institutes was to promote and stimulate regional development and relations with economic and social activities.

Figure 3. Map of Portugal Showing the Distribution of Higher Education Institutions

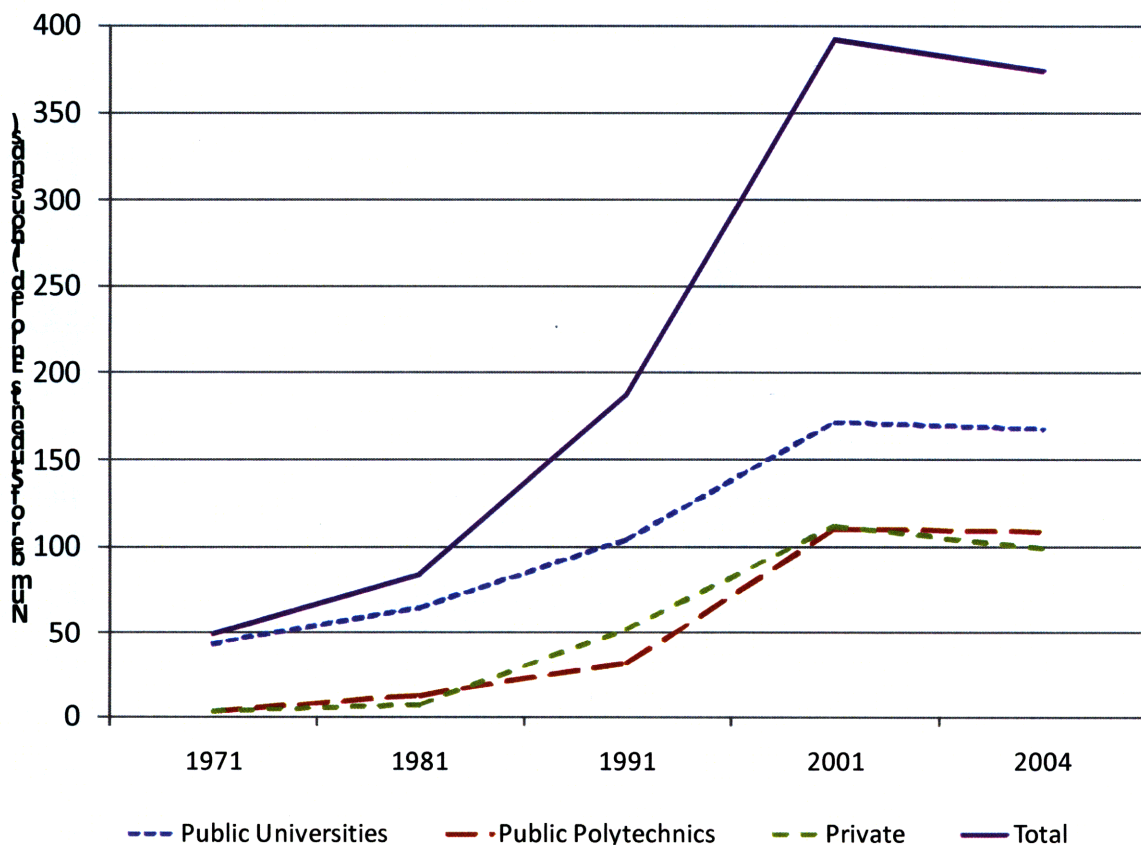


To this end, public polytechnics are distributed throughout all regions of the country, whereas private institutions and universities are concentrated near the more densely populated cities. This difference in distribution is illustrated by Figure 3 above, which plots the university and polytechnic institutions on a map of Portugal. The regional involvement of polytechnics extends beyond their distribution throughout the country; Portuguese law states that external stakeholders must comprise 20% of the general councils which govern the institutions. In practice, this means that polytechnics (more so than universities) are held accountable to the regions in which they are located. In contrast to universities, the research programs at polytechnics are focused on applied research, with closer ties to regional and local authorities (MCTES 2006). Additionally, Ferreira (2008) notes that local authorities have often placed pressure on the leadership of polytechnic institutions to create schools or programs in their regions that will meet particular regional needs. The network of polytechnics is intended to be more interactive with its environment and more fulfilling of the economic and social needs of the citizenry than the university system (Teixeira, Amaral et al. 2003). Dima (2005) observed that polytechnic courses are often related to the professional needs of the region in which they are located (Dima 2005).

3.2.2 Development

Before the 1970s, the higher education system in Portugal was homogeneous and elitist, and the number of students enrolled in higher education was extremely low. In the early 1970s, the higher education system in Portugal was opened to students of all social classes. An educational reform act from Parliament and the democratic revolution of 1974 further transformed the educational landscape (Ferreira, Machado et al. 2008). In the period of 1974-77, reforms were enacted to expand and develop the university sector. Then, in 1979, Portugal diversified its higher education system by implementing the binary system of universities and polytechnics. The development of the public polytechnic institution followed the World Bank's recommendations for vocationally oriented courses that would promote scientific, technological, and business studies (MCTES 2006). In 1979, Portugal also saw the introduction of private higher education institutions. These sweeping changes of the 1970s led to an explosion in the number of higher education enrollments in Portugal. As Figure 4 below shows, the number of enrolments nearly doubled in each decade from 1970 to 2000. This expansion was fueled in part by the Education Ministry's relaxation in 1988 of higher education enrolment requirements.

Figure 4. The Number of Students Enrolled in Higher Education in Portugal, 1971-2004



However, no single sector dominated the growth in higher education; the public university, public polytechnic, and private institution sectors each added roughly 120,000 students over the 30-year period. The diversification of program offerings was one of the primary policy goals in this expansion of higher education. But Amaral and Teixeira (2000) note that the goal of diversification has not been attained, and they partially attribute this to the ‘academic drift’ behavior of the polytechnics that was described in the previous subsection.

The trend of enrollment growth changed in 2001, when the country’s higher education enrolments began to decline. The OECD attributes the recent decline in Portuguese enrollments to the country’s demographic development. With declining birthrates, the population in the 15-24 year old age group is dropping and the growth rate in enrolments is not keeping pace with the rate of population decline (OECD 2007). This decline in candidates has led to excess vacancies at HEIs, causing some institutions to consolidate or close. Amaral and Teixeira (1999) analyzed the number of students in secondary education and predicted that the number of candidates for higher education will continue to drop until at least the year 2010. Amaral and Teixeira (2000) predict that polytechnics and private institutions will be hit the hardest by this decrease, since student surveys show that public universities are most students’ first choice for higher education, followed at a large distance by public polytechnics and private institutions.

As of 2008, the issue of higher education reform is high on Portugal’s national political agenda. The government demonstrated its commitment to reform in 2005, when the Minister of Science, Technology and Higher Education requested that the OECD conduct an education policy review for the country. Two other major evaluation efforts were launched to supplement the OECD review. The OECD’s review recommended that the distinctions between universities and polytechnics be clearly articulated and strengthened, so that these institutions can serve complementary rather than overlapping roles (OECD 2007). Beyond clarifying the roles of these institutions, the OECD recommended that the Portuguese government seriously evaluate how it will address the increasing number of higher education vacancies. With the further decreases in tertiary candidates predicted by education researchers, the higher education sector can expect to close or consolidate a number of institutions. The analysis in Chapters 4 and 5 will examine the relationship between the regional distribution of HEIs and industry in Portugal and will provide insight into how any downsizing might be effectively pursued.

3.2.3 Interaction with Industry

Interactions between higher education and industry in Portugal have traditionally been low. As evidence of this, Simões (2005) points out that Portugal's business-financed university R&D (as a percentage of GDP) is below 25% of the EU average. The Ministry of Science, Technology, and Higher Education (MCTES) blames the country's low R&D sponsorship on the fractured nature of Portuguese industry. Portuguese firms are typically small in size and thus their ability to perform or sponsor R&D is limited. Industry funding of R&D in Portugal is usually targeted to achieve short-term goals, not to invest in longer-term knowledge creation. Secondly, MCTES claims that, while Portugal has a large number of small firms, these firms are not entrepreneurial in nature, so they have little incentive to interact with HEIs to develop new products or services. Additionally, much of the demand for R&D in Europe (with R&D being a motive for HEI-industry interaction) is driven by multinational corporations. The number of multinational corporations (MNCs) operating in Portugal is quite small, and so is the number of MNC-sponsored projects (MCTES 2006).

There are signs, though, that Portugal is trying to stimulate academic-industry interaction. The Innovation Agency (AdI) was created in 1993 and restructured in 2002, with a mission to address some of the missing links between higher education-based R&D and industry (MCTES 2006). AdI is a state-owned agency, funded by the MCTES and the Ministry of the Economy and Innovation, and put in charge of the management of most public programs supporting research, development, technology transfer and the creation of new technology based enterprises. The agency provides various incentive programs to encourage applied research projects and it directly manages several multi-disciplinary R&D programs. AdI also cooperates with international institutions of the European Union, countries in Asia and Latin America, and transnational R&D organizations to foster partnerships with firms outside of Portugal. Portugal has had some difficulty coordinating research and innovation policies across its enterprises and academic institutions. The 2005 Technological Plan is meant to address this issue and to reduce redundancies and inefficiencies in Portugal's national system of innovation.

3.3 The United States' Higher Education System

The higher education enterprise in the United States is extremely large and diverse. In contrast to many other developed countries, the U.S. has no national system of education and institutional

policies in the U.S. are primarily market driven. This section will describe the structure and development of the U.S. system of higher education and will explain these aspects in more detail.

3.3.1 Structure

The “multipurpose” system in the U.S. is composed of universities, four-year colleges, community colleges, and vocational schools. In 2005, the U.S. had 4,352 institutions of higher education, which are distributed as shown in Table 4 below.

Table 4. The Breakdown of Higher Education Institutions in the United States⁵

Sub-Systems of Higher Education	Number of Institutions	Enrollment
Universities, 4-year colleges	2,848	10,840,000
Community / Vocational Colleges, 2-year or less	1,504	6,650,000
TOTAL	4,352	17,490,000

As the name of the “multipurpose” system implies, the U.S. higher education system is structured to meet a variety of different needs. Universities and four-year colleges conduct research and confer four-year and advanced degrees. The bachelor’s degree is the most common type of degree awarded and three degrees exist at the graduate level: the master’s degree, the professional degree, and the doctoral degree. Community colleges award two-year associate degrees, which may represent a terminal degree in a vocational field or may prepare students for enrollment at a four-year institution. Community colleges also provide an array of educational services to their communities, including specialized training for large employers and English language instruction for recent immigrants. Eckel and King (2004: 17) show some concern that these institution types are beginning to blur, stating that some community colleges have recently sought to offer four-year degrees. Cook (2000: 1) observes that the notion of a community college offering its own bachelor’s degrees seriously challenges traditional definitions of the community college role (Cook 2000). The issue is still debated, and some U.S. states have enacted laws prohibiting community colleges from offering bachelor’s degrees

In the U.S., the governance of public colleges and universities is the responsibility of each of the fifty states, rather than the federal government. Each state has the power to regulate the level of degree that institutions located within its borders can award. HEIs in the U.S. typically enjoy

⁵ American Council on Education (2007). *A Brief Guide to U.S. Higher Education: 2007 Edition*. Washington, DC, American Council on Education.. Data from 2005

more autonomy than those in Portugal, but the degree of government control varies tremendously from state to state. In some states, HEIs have constitutional autonomy as separate branches of state government. In other states, a governing board appointed by the state oversees all HEIs and sets funding levels, establishes accountability measures, and approves new academic programs. In still others, the state board only plays an advisory function and has little direct authority over institutions. Even though the federal government does not have explicit powers over HEIs, it is able to exert some influence on their activities. The federal government provides R&D grants and student loans for tuition payments (the federal government provided about \$100 billion in 2005 alone⁶) and much of this funding is conditional on institutions' compliance with federal statutes and information gathering policies.

The revenue sources of American institutions are diverse, and they vary for different types of institutions. The vast majority of community college institutions are publicly funded. In 2006, community colleges received an average of 42 percent of their revenue from state funds, 24 percent from local funds, and 6 percent from federal funds (American Association of Community Colleges 2006). For most universities and four-year institutions, state appropriations and tuition fees provide the bulk of funds for general operating expenses. Research universities also receive research money through federal grants and contracts. A very important source of funding that is somewhat unique to the U.S. is private donations. Private donations are especially important for the more prestigious universities and colleges. The total voluntary support for higher education reached \$25.6 billion in 2005 with almost half of the total donations coming from individual donors(American Council on Education 2007).

One hallmark that distinguishes the U.S. higher education system is the competition between HEIs at many functional levels. Institutions compete heavily to attract talented students and talented faculty. Higher education faculty are managed differently as well; in Portugal, HEI staff is employed by the national government, whereas faculty in the U.S. are employed by their respective institutions. Figure 5 and Figure 6 on the following page show the distribution of HEIs in the two states of interest in this thesis, Georgia and Pennsylvania. As was the case in Portugal, HEIs tend to cluster around urban population centers.

⁶ Ibid.

Figure 5. Map of Georgia Showing the Distribution of Population and HEIs

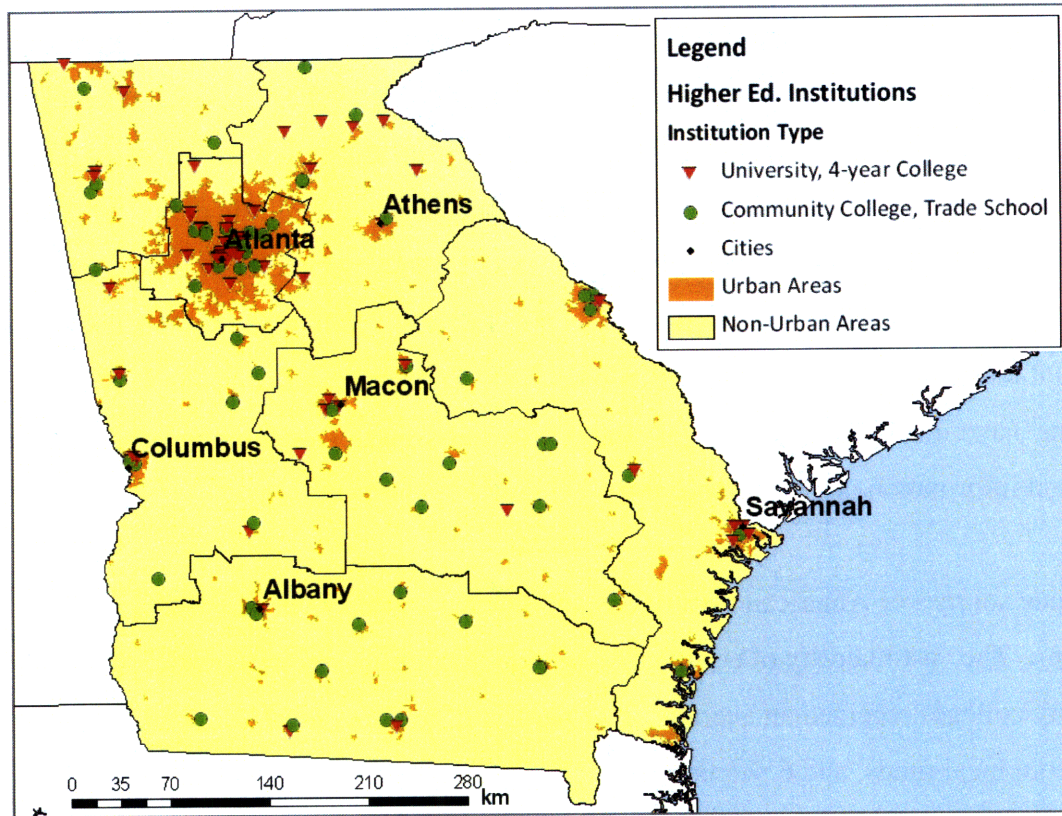
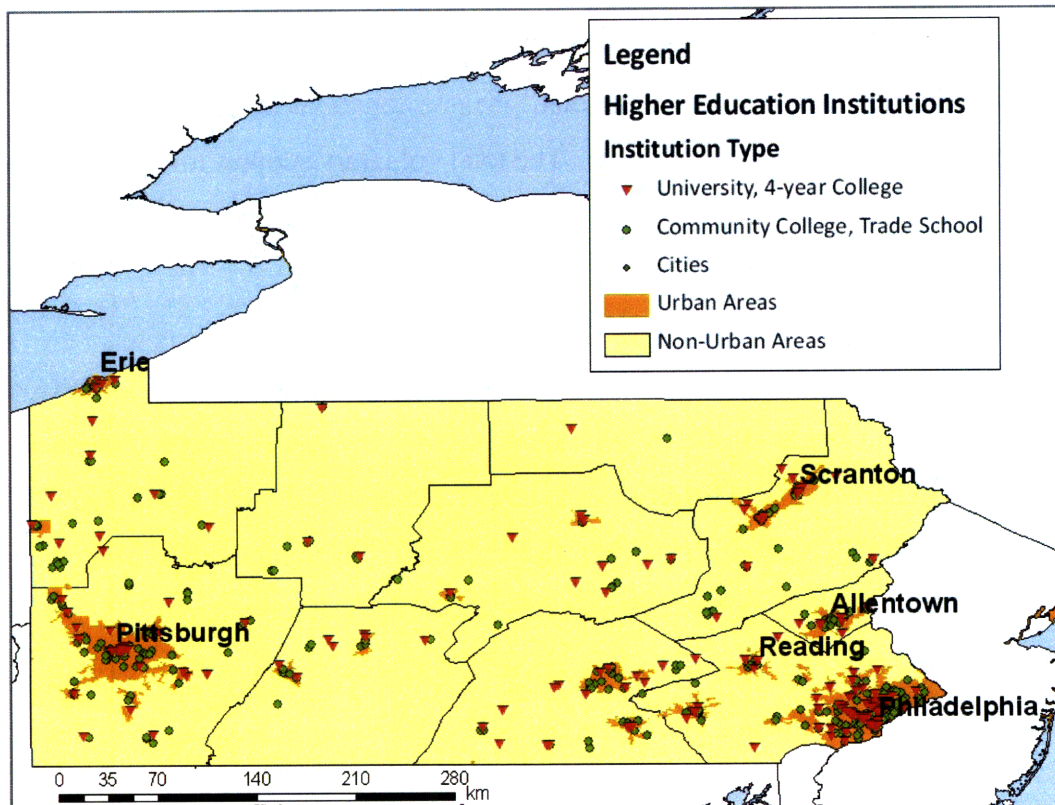


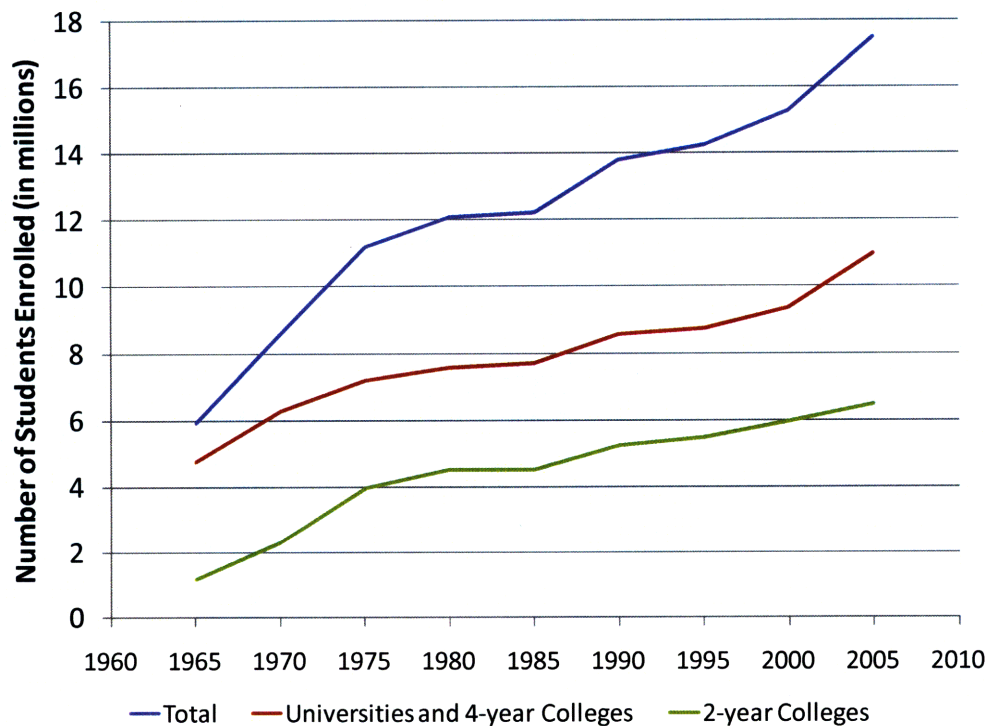
Figure 6. Map of Pennsylvania Showing the Distribution of Population and HEIs



3.3.2 Development

Higher education in the U.S. predates the nation's independence. Ten colleges existed when the U.S. declared its independence in 1776. Over the following two centuries, the number of academic institutions increased and the role of the American university was further defined. Alternatives to universities sprang up much earlier in the U.S. than in Portugal. Community colleges in the U.S. emerged in the late 1800s and early 1900s, when the schools were literally built and staffed by community members to help educate their neighbors. Some schools were seen as a vocational extension of high school while others offered technical education or lifelong learning. Though the community colleges' purpose was refined over the 20th century, the focus on career skills has not changed. The colleges served a workforce development purpose in the Depression Era 1930s and served a workforce re-training purpose when soldiers returned from World War II (Baker 1994). Since its inception, higher education in the U.S. has come at the price of tuition, which has limited access to a small portion of the population. Figure 7 below shows the surge in enrolments that occurred in the 1970s, when the federal government expanded access to higher education by offering low-interest student loans. Figure 7 shows continued growth through the remainder of the 20th century, as participation in higher education increased in traditionally underrepresented groups, such as women and minorities.

Figure 7. The Number of Students Enrolled in Higher Education in the U.S., 1965-2005



3.3.3 Interaction with Industry

Universities in the U.S. have a long history of industry-university collaboration. Bower (1992) traces this interaction back to the First World War, when academic and industrial scientists were brought together to solve urgent military problems. However, the U.S. saw few government policies in support of university-industry collaboration until the 1970s. The earliest federal effort to stimulate collaboration was in 1973, but the real movement began in 1980 when Congress passed the Bayh-Dole Act to foster the commercialization of university research. This and subsequent acts did not specifically intend to create a give-and-take relationship between industry and academia. Rather, the goal of this “collaboration” was to transfer academic research out of the labs and into growth-generating enterprise (Felman and Link 2001). At the national level, the National Technology Transfer Center serves to integrate industry, academia, and government agencies. However, most of the HEI-industry interaction is coordinated at the state and institution level. For example, the state of Georgia has several agencies that aim to link businesses with university research. Among these are the Georgia Centers of Innovation, the Southeast Regional Technology Transfer Center, and the Georgia Innovation & Technology Office. Many HEIs in Georgia and other states have their own technology transfer offices to commercialize the knowledge generated in their research facilities. The development of these technology transfer offices was largely initiated by the Bayh-Dole Act described above.

3.4 Comparison of the Two Systems

The descriptions in the previous two subsections draw many distinctions between the higher education systems in the U.S. and Portugal. The two systems have different tuition rates, different admissions procedures, and different degrees of institutional autonomy. A particularly significant point is that the U.S. system has evolved largely under market pressures which are now being modified by governmental actions, but the Portuguese system has evolved as a part of the government. The balance of this thesis will focus on one aspect in particular: the distinction between the U.S. “multipurpose” system and the Portuguese “binary” system. In this regard, these systems primarily differ in the “university alternatives” that they offer. Indeed, community colleges and polytechnics have very differently defined roles in their respective education systems. In the U.S., community colleges provide shorter-term, vocationally-focused education that is oriented primarily towards local students. Community colleges dominate the niche of occupational training and adult education, and they occupy themselves with little else. They are

“open enrollment” colleges, requiring only a secondary school diploma or the equivalent for admission. The majority of attendees are part-time students and many community college students who enroll have no intention of completing a degree⁷.

Portugal’s polytechnics were originally created to fill a similar regional and vocational role in Portugal, but they have since become less niche-oriented. Polytechnics serve students who are seeking an academic degree and the schools are only accessible to individuals with an acceptable performance on government-sponsored high-school graduation examinations. Observers have frequently noted the “academic drift” that has polytechnics encroaching on the role of universities. While American postsecondary education has remained committed to inventing courses of study or even whole institutions dedicated to the needs of its society and workforce, it appears that Portugal has gotten stuck framing the polytechnics as “almost-universities”. The literature suggests that the polytechnics are not wholly committed to regional service, either. Ferreira (2008) observed that the polytechnics tend to oscillate between regional and national service. This wavering characteristic of the polytechnics is one reason that the OECD called for Portugal to define more clearly the institutions’ role in the Portuguese educational system (OECD 2007).

This section concludes the background information portion of this thesis. The following three chapters will describe the methodology, results, and conclusions of a location-based analysis of the innovation systems in Portugal and the U.S. states of Georgia and Pennsylvania. The analysis builds on the innovation and education themes that were discussed in Chapters 2 and 3.

⁷ Some other purposes include: earning course credits to transfer to a four-year institution, earning a certificate in a specific skill, completing job-related training courses, or strengthening basic skills in writing or mathematics.

4 Methodology

The three main questions addressed in this analysis are as follows: (1) For the regions of Portugal and the U.S. states of Georgia and Pennsylvania, does the spatial distribution of industry coincide with spatial distribution of higher education (as measured by the number of graduates at schools of given locations)? (2) Is this relationship different for graduates from universities and graduates from university alternatives? (3) Is there a detectable correlation between HEI-industry co-location and firms' innovation output? Through comparisons between countries, or between types of institutions in the same country, we may observe differences in industry-academia relationships and how these relationships coincide with innovation creation. This chapter will lay out the method applied in my analysis, the data sources used, and the limitations of this method. I first present the hypotheses with which I approach the analysis. I then provide an overview of the method, with subsections that describe the specific analysis techniques in more detail.

4.1 Hypotheses

In the literature review which concluded Chapter 2, I observed that few, if any, studies have compared the innovation effects of universities and university alternatives. In my opinion, this is a significant gap in the literature. There are several possible reasons why prior research has largely ignored university alternatives. For one, there are few standards of comparison that can be applied between countries. Chapter 3's examination of the higher education systems in Portugal and the U.S. demonstrated that university alternatives have different roles in the two countries and the institutions themselves are not directly comparable. In fact, most international comparisons of university alternatives are difficult because the institutions cover a wide spectrum of academic courses. University alternatives may also be ignored because researchers perceive their contributions to the knowledge society as unimportant. While universities generate knowledge through research, "university alternatives" for the most part, do not.

However, I argue that university alternatives play an important role in countries' national systems of innovation. Though they don't contribute to the NSI in the sense of codifying knowledge (as universities do), they teach and train students, thereby increasing the qualification level of the labor force. University alternatives were championed in the 1960s by the OECD, the World Bank, and others, who claimed that they were a necessary means to prepare a nation's

workforce for modern occupations more associated with knowledge and information (Teixeira, Amaral et al. 2003). University alternatives are intended to fill the gap that existed in the labor force between those with a secondary school education and those with a college degree. University alternatives are often more flexible and responsive to industry and regional needs. Beyond simply increasing the supply of qualified labor, these institutions may also interact with industry through worker training and certification programs, or through industrial internships.

My hypothesis is that, because university alternatives are expected to engage with local industries, their course programs will show a geographic co-location with the industry sectors whose labor they supply. For instance, I expect that a community college located near a machinery manufacturer will be more likely to offer courses in machinery and tooling. I also expect that the university alternatives in the differently structured higher education systems of the U.S. and Portugal will exhibit different patterns of co-location with industry. I anticipate that, owing to these different interaction patterns, the “multipurpose” system and the “binary” system will exhibit different effects on industry innovation patterns in their respective regions. I also hypothesize that research-intensive industries (such as pharmaceuticals) will tend to concentrate near institutions that perform research, while less research-intensive industries (such as machinery fabrication) will not.

4.2 Overview

This section will provide an overview of the classifications and calculations used in the analysis. In brief, the following subsections will define the geographic areas for the study; select the target industries and define which academic courses pertain to them; describe the location quotients that determine the individual location and co-location of industry & academic concentrations; and describe the KPF used to regress the industry-academic co-locations against regional innovation outputs.

4.2.1 Geographic Regions Selected for Analysis

Rather than comparing the nation of Portugal to the entire United States, the scope of this analysis is limited to the U.S. states of Georgia and Pennsylvania. A comparison against the entire U.S. would be moot because of the difference in geographic and population scale. In addition, U.S. education policies are more state controlled while Portugal is nationally

administrated. Also, Georgia is the only U.S. state that publishes an industrial innovation survey with comparable methodology to the CIS in Portugal. The state of Pennsylvania is included in the concentration analysis to examine how the industry and graduate concentrations can vary between different U.S. states. The reader should note that, because Pennsylvania does not publish an innovation survey, it will not be included in the econometric portion of the analysis that addresses innovation creation. Table 5 below lists some relevant statistics of the geographic regions of interest. The data in the table show that Georgia and Portugal are of comparable population size and have a similar number of academic institutions. The regions are different, though, in that Portugal has almost twice the population density of Georgia, and Georgia has roughly twice Portugal's R&D spending and GDP per capita. Pennsylvania provides an interesting comparison to Georgia because, although the states are similar in population, area, and GDP per capita, Pennsylvania has roughly three times the R&D expenditures of Georgia.

Table 5. Demographic Comparison of the Regions of Interest

	Portugal	Georgia (US)	Pennsylvania (US)
Population, 2006 ^{8,9}	10,618,000	9,364,000	12,441,000
Land Area, sq. km ^{10,11}	92,000	150,000	116,000
Population Density per sq. km ^{8,9}	115	62.4	107
Number of Universities ^{12,13}	64	78	179
Number of "University Alternative" Institutions ^{12,13}	111	133	369
Number of sub-regions in innovation survey	7	7	n/a
Gross Expenditure on R&D, 2004 (US \$) ^{15,14}	\$1,412 M	\$3,665 M	\$10,813 M
Per capita GDP, 2005 (US \$) ^{15,16}	\$19,002	\$38,412	\$38,776

⁸ INE (2008). Statistical Data: Main Indicators, Instituto Nacional De Estatística.

⁹ U.S. Census Bureau (2008). American Factfinder: Population Finder. American Factfinder, U.S. Census Bureau.

¹⁰ CIA (2008). World Factbook. Washington, DC, Central Intelligence Agency.

¹¹ NACO. (2008). "About Counties: Data & Demographics." Retrieved 13 Nov 2008, 2008, from <http://www.naco.org/>.

¹² Ferreira, J. B., M. d. L. Machado, et al. (2008). The Polytechnic Higher Education Sector in Portugal. Non-University Higher Education in Europe. J. S. Taylor, Springer Netherlands. **23**: 191-214.

¹³ NCES (1997-2004). The Integrated Postsecondary Education Data System (IPEDS) Dataset Cutting Tool, U.S. Dept. of Education, Institute of Education Sciences, National Center for Education Statistics.. These figures count satellite campuses as additional schools.

¹⁴ NSF (2006). National Patterns of R&D Resources: 2006, U.S. National Science Foundation.. These figures count satellite campuses as additional schools.

¹⁵ Eurostat (2008). General and Regional Statistics, Eurostat, Statistical Office of the European Communities.

¹⁶ U.S. Bureau of Economic Analysis (2008). Gross Domestic Product by State, U.S. BEA.

Each of the regions selected for analysis is divided into geographic sub-regions, which are pictured in Figure 8 and Figure 9. Ideally, this analysis would examine the industry and higher education distributions at a low geographic aggregation, looking at the level of counties or municipalities. However, industrial data is only available for aggregated geographic areas because of concerns regarding the disclosure of confidential industrial data. So, while the sub-regions described here are not ideal, they represent the best data that is publicly available.

Figure 8 below depicts the seven geographic sub-regions of Portugal. These regions are delineated by the Nomenclature of Territorial Units for Statistics (NUTS), as it is defined by the European statistics agency, Eurostat. The NUTS regions are based primarily on the institutional divisions already in force from the Portuguese Commission for Coordination and Regional Development (Eurostat 2008). Additional statistical information regarding Portugal's sub-regions is included in Appendix B.

Figure 8. Map of Portugal with NUTS II Sub-regions

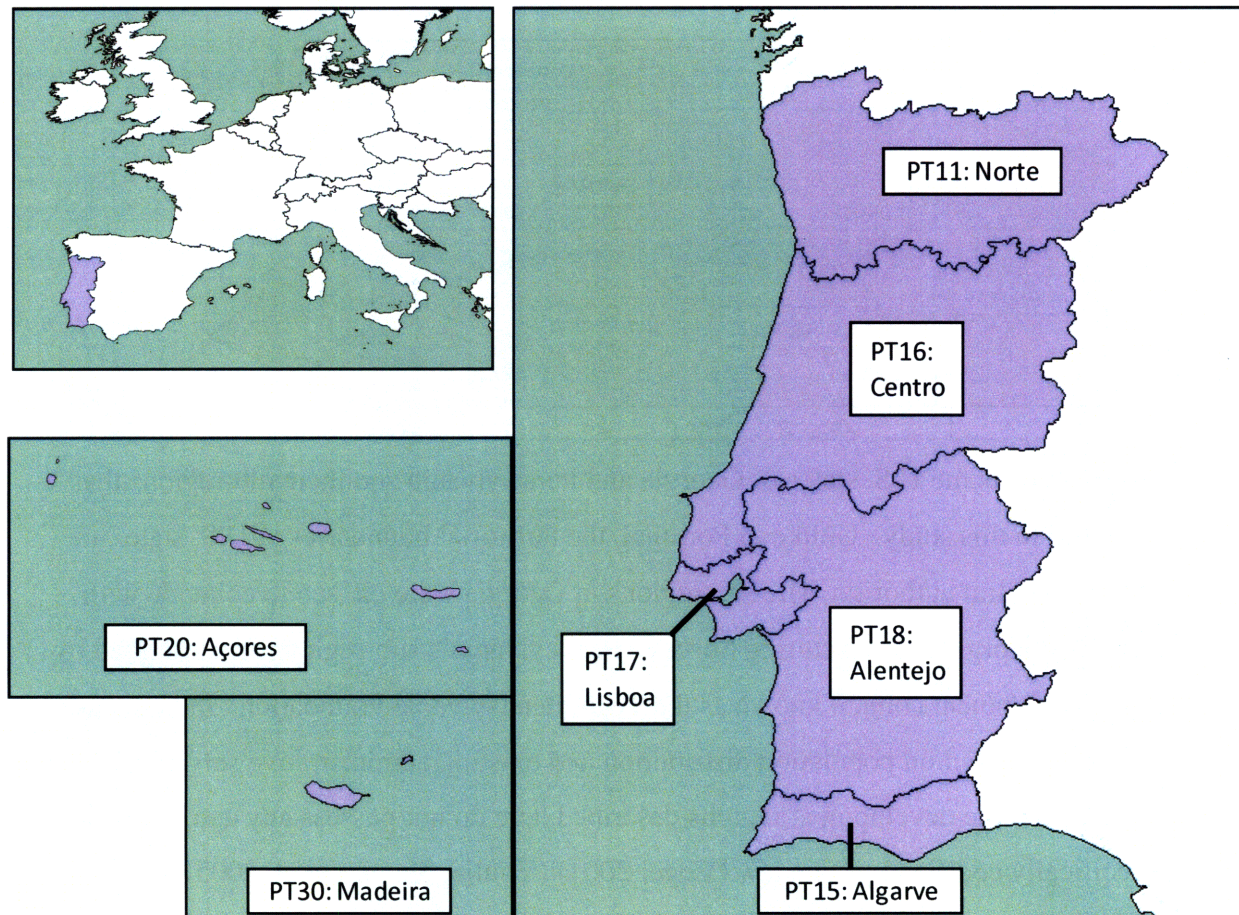


Figure 9. Maps of (a) Georgia and (b) Pennsylvania, with Sub-regions

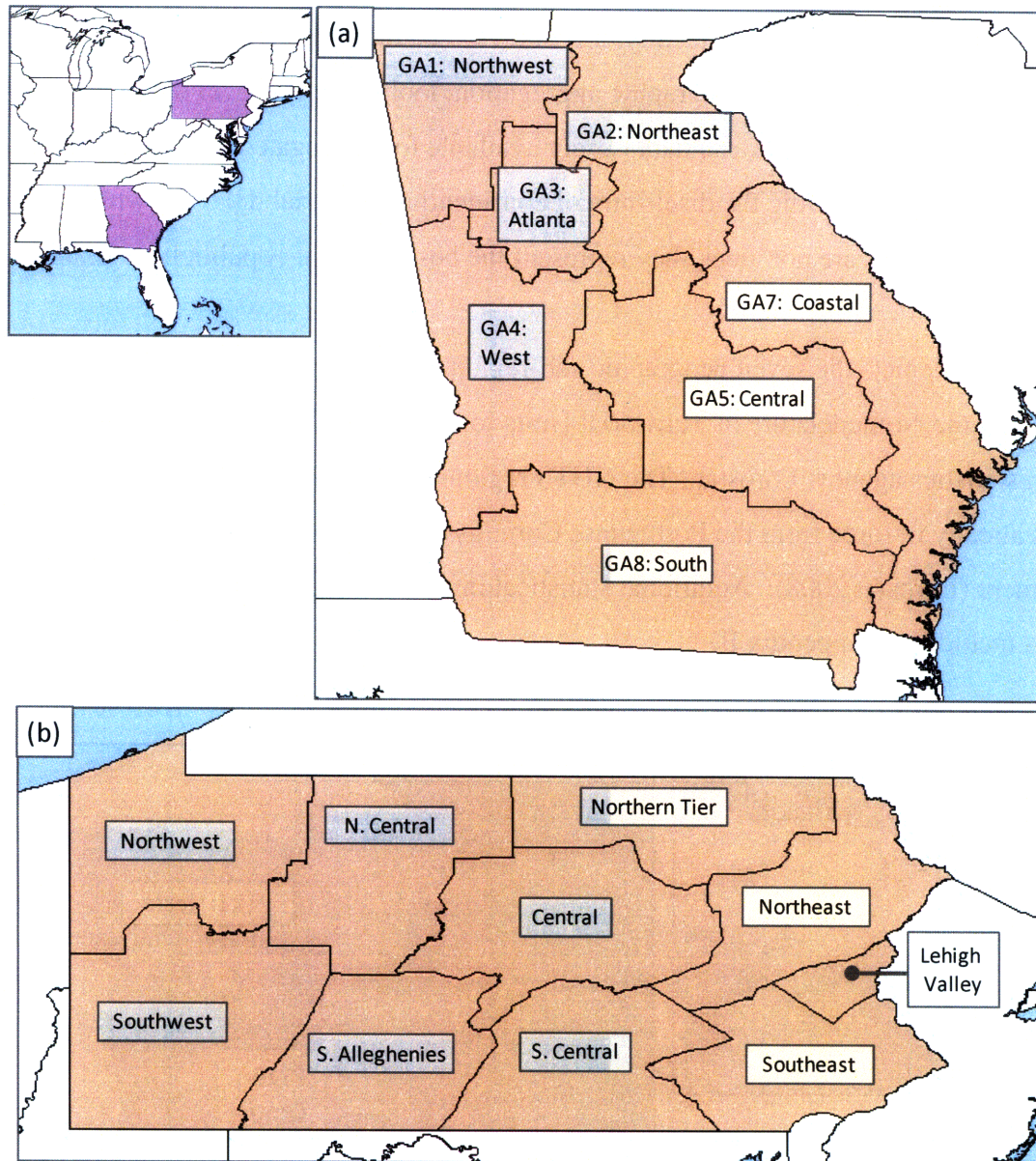


Figure 9 above depicts the U.S. states of Georgia and Pennsylvania and their sub-regions that will be examined in this study. Unlike in Portugal, the territorial boundaries in U.S. states are not decided by a central authority. The sub-regions in Georgia were chosen to coincide with those used in the Georgia Manufacturing Survey. Pennsylvania's sub-regions are described by an economic development council known as the Team Pennsylvania Foundation. In both cases, the sub-regions are based on population distribution and existing administrative service regions. However, the economic development regions described here do not possess any autonomy, nor are they specifically codified by state law (Vogel 2001) (Youtie, Shapira et al. 2005).

4.2.2 Quantifying Innovation Outputs

Section 2.2 describes the difficulties associated with using patent-generation data to quantify the outputs of the innovation process. One further issue with using patents in this analysis is that patenting activity in Portugal is very low. In 2004, there were only 17 USPTO patents¹⁷ and 49 EPO patents¹⁸ that originated in Portugal. Compare these figures to those for the U.S. state of Georgia, which in 2004 was granted 1326 USPTO patents and an estimated 470 EPO patents¹⁹. It is possible that patenting activity is limited in Portugal because Portuguese industry is predominantly made up of small businesses, which may not be able to afford the costs associated with filing and defending a patent. In any case, the low patenting activity in Portugal is remarkable and it mitigates further against the use of patents as a metric because patent statistics would not produce a very strong locational signal for Portugal. Thus, rather than patent statistics, this analysis will use innovation survey data as a measure of innovative output.

4.2.3 Data Sources

This analysis that follows brings together three main bodies of data: industry data, higher education data, and innovation data. The U.S. and Portugal have different agencies that gather and disseminate this data. Industry data for Portugal was taken from Eurostat's database of "Structural Business Statistics" (Eurostat 2008). Industry data for the U.S. comes from the U.S. Census Bureau. Data on the number employees and wages is from the "Local Employment Dynamics" database of Quarterly Workforce Indicators (U.S. Census Bureau 2002) and data on the number of business establishments is from the "County Business Patterns" database (U.S. Census Bureau 2002). Portugal and the U.S. use different classification systems for industrial activity and the harmonization between these systems is discussed in Section 4.2.4.

The education data used in this analysis includes the number of graduates from universities and university alternatives, categorized by institution type and by program of study. For Portugal, this data was retrieved from Portugal's Center for Science and Technology under the Ministry for Science, Technology, and Higher Education (OCES and Superior) 2007). For the U.S.,

¹⁷ USPTO. (2008, 13 Jun 2008). "Patenting By Geographic Region (State and Country), Breakout By Technology Class." Retrieved 13 Nov 2008, 2008, from http://www.uspto.gov/go/taf/clsstc/ptxstcc1_gd.htm.

¹⁸ Eurostat (2008). General and Regional Statistics, Eurostat, Statistical Office of the European Communities.

¹⁹ The estimated number of EPO patents originating from Georgia is based on Georgia's share of U.S. patenting (1.6%) and the number of 30,126 EPO patents originating from the U.S. in 2004 NSF (2008). Science and Engineering Indicators 2008. Washington, DC, National Science Foundation..

education data was retrieved from the U.S. Department of Education's Integrated Postsecondary Education Data System (NCES 1997-2004). The U.S. and Portugal use different taxonomies for the classification of higher education courses and the harmonization of these systems is discussed below in Section 4.2.4.

The sources of innovation survey data are the 2005 Georgia Manufacturing Survey (GMS) and the fourth Community Innovation Survey (CIS4). The GMS was administered in Georgia by the Georgia Tech's Enterprise Innovation Institute and the Georgia Tech School of Public Policy (Youtie, Shapira et al. 2005). The CIS4 was administered in Portugal and published in 2006 by the Center for Science and Higher Education (Gonçalves, Vieira et al. 2006). Three specific measures from these surveys are used in this analysis: (1) the number of businesses that claimed to have innovation activities, (2) the number of innovating businesses citing HEIs as an important source of information in their innovation activities, and (3) the number of innovating businesses that partnered with an HEI. These surveys are described in detail in Section 2.2.3 above. The GMS and CIS4 distinguish firms that are innovative using guidelines from the Oslo Manual, which states that "a technological product and process innovating firm is one that has implemented technologically new or significantly improved products or processes or combinations of products and processes during the period under review"(OECD Statistical Office of the European Communities 2005).

4.2.4 Industries and Courses Selected for Analysis

This analysis is limited to the examination of "high technology" industries and the higher education courses which pertain to them. "High technology" can be defined as a kind of production activity that fundamentally depends on research and development (Varga 1998). Varga (1998) cites three criteria for the identification of high technology sectors: the ratio of R&D to sales, the percentage of employees that are engineers and/or scientists, and the number of innovations per 1000 employees. The set of industries in this analysis were selected by Audretsch and Feldman (1994) and Feldman (1994) based on these criteria. The current research is constrained by the fact that regional innovation data is only available at the two-digit industry classification code level. Thus, this is the level of aggregation on which this analysis will focus. The resulting set of sectors with NACE classification codes is as follows: Oil Refining (DF23), Chemistry & Pharmaceuticals (DG24), Rubber & Plastics (DH25), Machinery (DK29),

Computers & Office Machinery (DL30), Electronics (DL31), Electrical Engineering (DL32), Scientific Instruments (DL33), and Transportation Vehicles (DM34-35). A final “High Tech” sector represents the combination of these nine sectors. The U.S. and Portugal use different industry classification systems. The NACE system used in Portugal classifies industries based on the products that they produce, whereas the North American Industry Classification System (NAICS) used in the U.S. classifies industries based on the production methods that they incorporate. The NAICS categories used in this analysis were harmonized with NACE categories using tables from the U.S. Census Bureau, and are listed in Table 6 below (U.S. Census Bureau 2004). This analysis measures the co-location of industry concentrations with the academic courses that are associated with them. Table 6 below presents the academic courses associated with the different industry classifications considered in this analysis. These associations are drawn from prior work by Fischer and Varga (2003), Varga (1998), and Audretsch and Feldman (1994). Their categorizations were, in turn, based on industry surveys conducted by Levin et al. (1987).

The U.S. and Portugal do not share a common system for classifying higher education courses. The U.S. Dept. of Education classifies higher education courses using hierarchical Classification of Instructional Programs (CIP) codes (NCES 2000). The Portuguese Ministry of Science, Technology, and Higher Education classifies courses according to the National Classification of Fields of Education and Training (CNAEF) system, which is harmonized with the Eurostat statistics agency classifications for comparability across the EU. It was necessary for this analysis to identify the higher education courses in the U.S. and Portugal that are relevant to the industries of interest, as listed in Table 6 below. This was achieved by performing keyword queries with the lists of courses in the CIP and CNAEF classifications. For example, Table 6 shows that the courses relevant to the “Chemistry & Pharmaceuticals” sector (NACE: DG24), include “Chemistry-, Pharmaceuticals- and Medicine-Related Courses including Microbiology, Pharmaceutical Chemistry, Biochemistry”. To identify courses in these categories in the U.S. and Portugal, the CIP and CNAEF course lists were queried with the keyword string, “chem* OR pharm* OR medic* OR bio*”. The results were then subjectively examined to remove results that are irrelevant to the “Chemistry & Pharmaceuticals” sector, such as “CIP 26.0709:

Table 6. High Technology Industrial Categories and their Associated Academic Courses

NACE Category²⁰	NAICS Category²¹	Industry Sector	Associated Academic Courses
DG23	324	Oil Refining	Chemistry-Related Courses including Materials Sciences, Chemical Engineering and Core Chemistry except for certain sectors such as Quantum Chemistry, Biochemistry and Geochemistry
DG24	325 less 3252	Chemistry & Pharmaceuticals	Chemistry-, Pharmaceuticals- and Medicine-Related Courses including Microbiology, Pharmaceutical Chemistry, Biochemistry, etc.
DH25	326 & 3252	Rubber & Plastics	Chemistry-Related Courses including Materials Sciences, Chemical Engineering and Core Chemistry except for certain sectors such as Quantum Chemistry, Biochemistry and Geochemistry
DK29	333	Machinery	Engineering Courses including Mechanical Engineering and Electrical Engineering, Heat Science, Thermodynamics, Material Sciences, Computer Sciences, Technical Mathematics
DL30	3341 & 3333	Computers & Office Machinery	Courses connected with Information Technologies, Micro-Electronics, Automation and Robotics, Computer Sciences, etc.
DL31	3344 & 335 less 3359	Electronics	Electrical Engineering, Micro-Electronics, Technical Mathematics, Automation & Robotics, Computer Sciences, etc.
DL32	3342 & 3359	Electrical Engineering	Electrical Engineering, Micro-Electronics, Technical Mathematics, Automation & Robotics, Computer Sciences, etc.
DL33	3345 & 3391	Scientific Instruments	Engineering Courses such as Mechanical Engineering, Electrical Engineering, Micro-Electronics, Automation & Robotics, Technical Mathematics, Computer Sciences, Physics-Related Fields, Medicine-Related Fields, Biology-Related Fields, Materials Sciences, etc.
DM34-DM35	336	Transportation Vehicles	Engineering Courses including Mechanical Engineering and Electrical Engineering, Heat Science, Thermodynamics, Material Sciences, Computer Sciences, Technical Mathematics, Astronomy, Transport Science

Wildlife Biology.” The result of this course identification procedure is a table of relevant course codes associated with each industry. This table of results was then applied to databases of graduate statistics to return the number of graduates (by geographic location and HEI type) relevant to each industry. These statistics on HEI graduates are used to approximate the size and

²⁰ NACE is the standard classification system for economic activity in Portugal and the European Community.

²¹ North American Industry Classification System (NAICS) is the standard system for economic activity in the U.S.

geographic distribution of the educational programs that are associated with each industry sector. The limitations inherent in associations of this sort are discussed below in Section 4.3.

4.2.5 Identifying Co-locations of Industry and Higher Education

The previous subsection listed the industries that are considered in the analysis and the academic courses associated with them. The analysis uses a Location Quotient (LQ) calculation to identify where these industries and academic courses are concentrated. The location quotient is covered in depth in regional economics texts (Isard, Azis et al. 1998) (Bendavid-Val 1991); a summary and example are presented here. The location quotient is a device that is commonly used to gauge the relative concentration of a selected industry category in a geographic region. The location quotient is essentially a ratio of ratios. The method is illustrated here using the measure of employment. For the geographic region of interest and a reference area, the employment in a selected sector of activity is related to total employment by means of a simple ratio computation. Then, the ratios for the regional and reference area levels are compared by means of another ratio computation. The formula for computing the location quotient (LQ) is below:

$$LQ = \frac{\frac{E_{i,r}}{E_{T,r}}}{\frac{E_{i,n}}{E_{T,n}}} \quad (1)$$

where

- $E_{i,r}$ = employment in industry i in the region r
- $E_{i,n}$ = employment in industry i in the reference area n
- $E_{T,r}$ = total employment in the region r
- $E_{T,n}$ = total employment in the reference area n

The result of the location quotient for a given industry and region can be evaluated using the following rules:

- LQ > 1: If the location quotient is greater than 1, the region has a relative concentration in the study sector, compared to the reference area
- LQ < 1: If the location quotient is less than 1, the region does not have a relative concentration in the study sector, compared to the reference area.
- LQ = 1: If the location quotient is equal to 1, the region has the same concentration of the study sector as the reference area.

For robustness, industry concentrations are often identified by calculating regional location quotients using several different industry measures, such as employment, wages, and number of firms. These seemingly redundant calculations can prevent misidentification of industry concentrations. Suppose, for example, that a hypothetical region Y is home to two individuals with extremely high wages in a hypothetical industry X, but that the sector houses no other activity in Industry X. By most definitions, these two individuals would not constitute an industry concentration, but an LQ calculation using only the “wages” indicator could identify region Y as an industry concentration. However, a procedure that incorporates other industrial measures in addition to wages would likely not flag region Y as an industry concentration (and correctly so, provided that the reference area has some industry X activity outside of region Y).

To enhance robustness, this analysis follows the method used by the Dermastia (2005), who examined regional industry concentrations in Slovenia (Dermastia 2005). Dermastia calculated the location quotients for four different business indicators and identified a regional industry concentration when at least three of the four indicators showed an LQ greater than a cutoff value for a given region (Dermastia used a cutoff value of $LQ > 1.5$). The following analysis calculates location quotients for three business indicators: (1) the number of enterprises, (2) employment in the industry, and (3) quarterly wages. These LQs are calculated for the three business indicators in each of the nine industry sectors of interest for each of the geographical sub-regions in Portugal, Georgia, and Pennsylvania. For these Industry LQ calculations, the geographic regions of Portugal, Georgia, and Pennsylvania are used as the ‘reference areas’ for their respective sub-regions. Industry concentrations are identified where, for a given region and industry, at least two of the three indicator LQs are greater than a specified cutoff value. Initially, I use a cutoff value of $LQ = 1.0$ to demonstrate where sectors show slight concentrations; then I use cutoff values up to $LQ = 1.5$ to show where sectors are strongly concentrated. Figure 10 below illustrates the calculation for a hypothetical Region Z.

Figure 10. Illustrative Location Quotient Computation: High Tech Sector in Region Z

	Employment in High Tech Sector	Total Employment, all sectors
Region Z	150	260
Nation	10,000	24,000
$LQ = \frac{\frac{150}{260}}{\frac{10,000}{24,000}} = \frac{0.58}{0.42} = 1.38$, showing that Region Z has relative concentration in High Tech.		

In addition to industry concentrations, this thesis measures the relative concentrations of HEI graduates from programs that are associated with the sectors of interest. My assumption here is that the number of graduates from an academic course of study is a proxy for the size of that course. The previous section of this thesis described how academic courses (and their graduates) are associated with different industries and how the number of course graduates is extracted from the education data. In this analysis, I use the ‘number of graduates’ from academic courses (related to the industry sectors of interest) at universities and university alternatives in a location quotient calculation for the sub-regions in Portugal, Georgia, and Pennsylvania. As with the Industry LQ calculations, these Graduate LQ calculations use the geographic areas of Portugal, Georgia, and Pennsylvania as the ‘reference areas’²². This method will identify, for example, whether a certain region has a higher-than-average concentration of HEI courses associated with the “chemistry & pharmaceuticals” sector²³. Again, the LQ calculation will identify a higher-than average concentration of graduates where the LQ is greater than a cutoff value; the cutoff value will again be examined from $LQ = 1.0$ to $LQ = 1.5$ to gauge the strength of the identified concentrations.

After the location quotient method has been used to identify industry and academic clusters, the cluster locations will be intersected to see in which regions industry and HEIs are co-located. Recalling the questions from the beginning of this chapter, I hope to examine the differences in co-location trends (1) between universities and university alternatives, and (2) between Portugal and the U.S. If these trends are different for community colleges and polytechnics, then the results may illuminate differences in how the university alternatives in the U.S. and Portugal are addressing their goals of regional integration. The industry and graduate LQs and the co-location results are detailed in Chapter 5.

²² Data availability limits our ability to use a large reference area such as the OECD, which is shared by all the sub-regions of interest. While the OECD provides tertiary graduate data for most OECD countries, the academic courses are highly aggregated, so this data could not be used to identify courses relevant to particular industries.

²³ A literature search did not uncover any prior research that has used location quotients to examine the regional distribution of academic courses. As mentioned in the literature review (Section 2.4), several researchers have used higher education R&D spending to examine the geographical effects of university presence on industrial innovation. Keeping in mind that the community colleges in the U.S. do not perform research and that the polytechnics in Portugal perform less research than universities, the use of R&D statistics would not be appropriate to measure the presence of the university alternatives considered in this study.

4.2.6 Regression Using the Innovation Production Function

For my analysis, I will test the significance of HEI and industry co-locations in the innovation production function. This analysis will use a production function of the Cobb-Douglass form, similar to the knowledge production function developed by Griliches. This equation takes the following form:

$$I = C^a Z^d \varepsilon \quad (1)$$

where I is the innovation activity measured by the Community Innovation Survey, C is a measurement of co-location between HEIs and industry in selected sectors, and Z is a vector of variables that reflects the economic and institutional additional determinants. Z is used to control for the effects of other regional factors which may also influence innovation output. The vector Z includes measurements of R&D expenditure, GDP per capita, and population density; all of which are believed to significantly influence innovation. The data for the Z vector is presented in Appendix B. The exponents a and b determine the correlation of the inputs C and Z with the output K . The logarithmic form of this equation can be used in Ordinary Least Squares analysis:

$$\ln I = a \ln C + d \ln Z + \varepsilon \quad (1)$$

The innovation data, I , is taken from the fourth Community Innovation Survey, which was conducted in 2004. I is the percentage of regional firms that claim to have introduced a product or process innovation in the period 2002-04. The co-location measurement, C , combines data on industry activity and higher education graduates. The value of C represents the highest location quotient values for the co-location of industry and education. Industry activity data is sampled or imputed for the period 2002-04 and HEI data is taken over the period 1997-2004. The vector Z uses data from 2002.

4.3 Limitations

In the preceding description of my analytical method, I alluded to several limitations inherent in my analysis. I believe that the exercise of associating academic programs with industries will be a large source of error. Many students who graduate from specialized programs choose to pursue employment in careers outside of their specialization. Looking at the issue from a different perspective, we can observe that specialized businesses need skills from outside of their specialization. For example, administrative assistants, accountants, and lawyers are employed in most areas of business. While the association of academic courses and industry sectors attempts

to include the courses which are most relevant to different industries, the result will not completely correspond to the full labor needs of any given industry. Nonetheless, the sectors that we are trying to study are those which should show locational effects if they exist.

Another limitation is in the use of the number of HEI graduates in the calculation of program concentration. Though the number of graduates is a reasonable proxy for the *size* of an academic program, this figure offers no information about the quality or productivity of an academic program. More so than the size of a program, its quality and productivity may govern to what extent it interacts with local industry. For example, an academic program that uses its resources efficiently may be able to dedicate a larger portion of its budget to initiatives that engage local businesses. Unfortunately, neither institution budgets nor measurements of program quality are available for the regions of interest in this thesis.

This analysis is also limited in that it aggregates industries and academic courses by region and does not consider the inter-regional interaction of HEIs and industry. Any analysis of geographically aggregated data has an inherent boundary effect. HEIs at the border of one region may interact with businesses in neighboring regions and thus introduce error into a spatially aggregated correlation. Additionally, an increasing number of students (especially at the vocational level) are pursuing “distance learning” through online courses or correspondence learning materials. These individuals may reside and interact with businesses in one region, while taking correspondence courses at an HEI in another region. Of course, it is in the interest of regional administrators to encourage HEIs (especially those receiving public funds) to keep their activities within the region and contribute to intra-regional economic growth. However, it is not clear how intensely U.S. and Portuguese regional administrators advocate activities that promote intra-regional engagement. These inter-regional effects, both from boundary effects and from distance learning, are certain to impact the results of this analysis to some degree.

Another limitation in any regional analysis is in the definition of the regions themselves. The regions in my analysis are defined in Section 4.2.1 and were chosen because they represent the lowest aggregation of data that is publicly available. The sub-regions in Europe are defined by a central European statistics agency and the sub-regions in the U.S. are based on economic development regions defined by the states themselves. In both cases, the sub-regions exhibit

minimal autonomy with regards to the governance of higher education and industry. In Portugal, this governance is mostly centralized in a national authority, and governance in the U.S. is shared between local and state authorities. Thus, there is little coordination at the sub-regional geographic level used in this analysis. This means that data at the sub-regional level could reflect a collection of disparate local effects that could confound results at the regional level.

5 Results and Analysis

The previous chapter described the methodology that was applied in the data analysis portion of this thesis. This chapter describes the results that obtained when this methodology was applied. Section 5.1 presents the industry and academic concentrations in the areas of interest and examines the co-location of these concentrations. These results show how industries overlap in space with the academic programs that could cooperate with them. Section 5.2 presents the results of the econometric regression study, which show the correlation between the co-location data and the innovation survey data. Then, Section 5.3 offers an interpretation of the results.

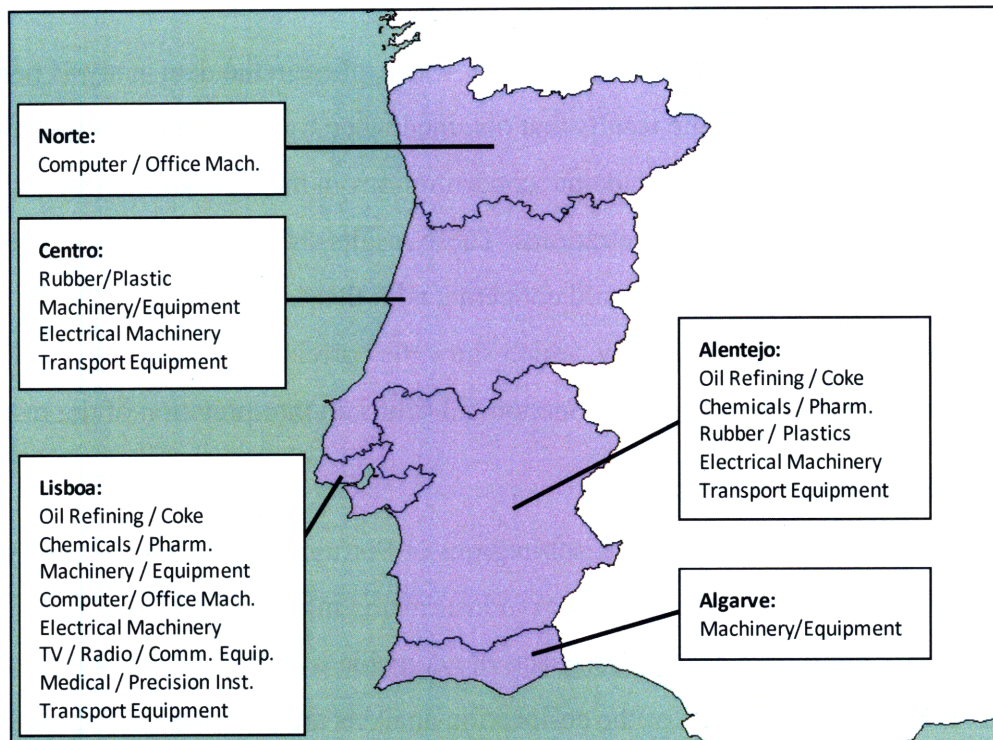
5.1 Co-location Analysis Results

The co-location analysis determined which sub-regions of Portugal, Georgia, and Pennsylvania have higher than average concentrations in *both* industrial and higher education activity. That is, it answers the question, “Where does industry activity coincide with higher education activity for given industry sectors?” The results of the co-location analysis are presented in three sub-sections: First, the industry concentrations are presented for the three regions of interest. Next, the higher education concentrations are identified. Then, the intersection between these industry and higher education concentrations are presented to show which sub-regions exhibit co-locations for the technology industry sectors in this analysis. Each region in the analysis shows a different pattern of concentrations, but in general, the results confirm the hypotheses that were put forth in Section 4.1.

5.1.1 Industry Concentrations

To identify the relative concentrations of different industry sectors in Portugal, Georgia, and Pennsylvania, I calculated location quotient (LQs) for three business statistics (number of enterprises, number of employees, and quarterly wages). I identify industry concentrations where at least two of these three LQs are greater than 1.0. Over the following three pages, the identified concentrations are presented with some observations. Each presentation includes a map of the region with shaded sub-regions indicating the number of industry concentrations present in each sub-region. Each presentation also includes a table of Location Quotients for the sectors included in this study. The LQs shown in these tables are the median of the three industry LQs, and are meant to represent the strength of the sector concentration in each region.

Figure 11. Map of Industry Concentrations Identified in Portugal



Note: The Azores and Madeira regions are not pictured because they do not contain industrial concentrations.

Table 7. Industry Concentrations in Portugal: Median Industry LQ

Region	Norte	Algarve	Centro	Lisboa	Alentejo	Açores	Madeira
DF23: Petrol/Coke	0.7	0.6	0.0	1.8	5.2	0.3	0.2
DG24: Chem/Pharm	0.5	0.2	0.7	2.5	1.5	0.0	0.0
DH25: Rubber/Plastic	0.9	0.4	1.4	0.8	1.0	0.2	0.4
DK29: Mach./Equip	0.8	1.1	1.4	1.2	0.6	0.1	0.5
DL30: Comp./Office	1.3	0.0	0.6	1.0	0.0	0.0	0.0
DL31: Elec. Mach.	0.5	0.2	1.0	2.0	1.1	0.1	0.4
DL32: TV/ Comm.	0.7	0.1	0.3	3.0	0.9	0.0	0.0
DL33: Med., Prec. Instr.	0.9	0.9	0.5	2.3	0.1	0.0	0.0
DM34-5: Transport Equip.	0.6	0.5	1.3	1.6	2.1	0.2	0.1
High Tech	0.7	0.5	1.1	1.6	1.3	0.1	0.3

Table 7 is a matrix that shows the median location quotient of three business indicators for the technology industries in the sub-regions of Portugal. The matrix cells with median LQ > 1 are highlighted (indicating a relative industry concentration) and gradient shading shows the strength of the concentration. Figure 11 plots these industry concentrations of a map of Portugal. The results show that technology industries in Portugal are concentrated in the Centro, Lisboa, and Alentejo regions, with the highest number of industry concentrations near the urban region of Lisboa. The Norte and Algarve regions show a concentration of one technology industry each; the island regions of Açores and Madeira have very low activity in these industries.

Figure 12. Map of Industry Concentrations Identified in Georgia

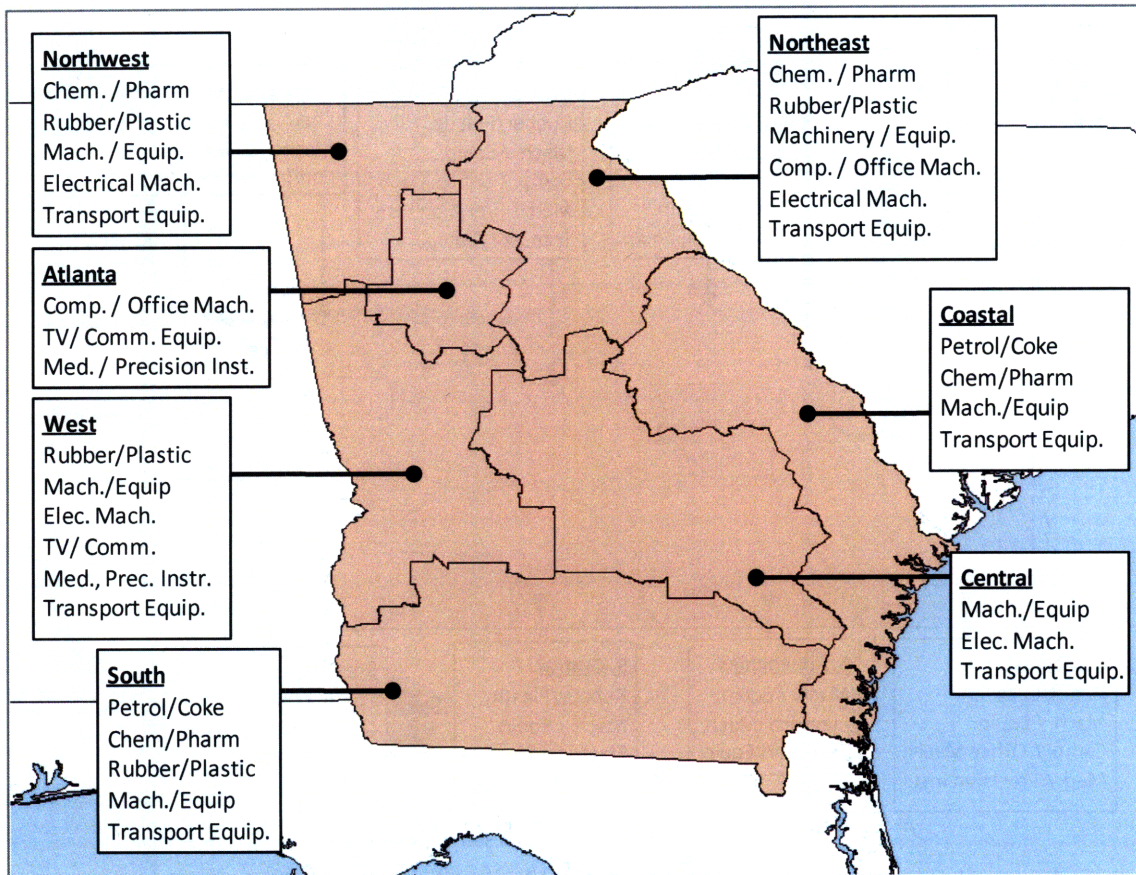


Table 8. Industry Concentrations in Georgia: Median Industry LQ

Region	NW GA	NE GA	Atlanta	West	Central	Coastal	South
DF23: Petrol/Coke	0.1	0.5	0.9	0.8	0.1	2.9	1.1
DG24: Chem/Pharm	1.7	2.0	0.7	0.7	0.3	1.8	1.0
DH25: Rubber/Plastic	2.1	1.5	0.7	1.9	0.5	0.6	2.0
DK29: Mach./Equip	1.4	2.4	0.5	1.2	2.1	1.0	1.3
DL30: Comp./Office	0.1	1.9	1.3	0.0	0.1	0.0	0.9
DL31: Elec. Mach.	1.7	1.3	0.8	3.5	1.6	0.1	0.2
DL32: TV/ Comm.	0.0	0.5	1.2	2.3	0.0	0.2	0.8
DL33: Med., Prec. Instr.	0.2	2.2	1.0	1.0	0.5	0.9	0.2
DM34-5: Transport Equip.	1.1	1.6	0.5	1.9	1.2	2.2	1.5
High Tech	1.3	1.7	0.7	1.8	1.0	1.1	1.3

Figure 12 and Table 8 above present Georgia’s industry concentrations in the same fashion as on the previous page. The distribution of industries relative to population centers in Georgia is strikingly different from Portugal. Georgia’s most densely populated sub-region, Atlanta, shows the state’s smallest number of industry concentrations. Atlanta is the only region in Georgia without an industry base in the “Machinery & Equipment” and “Transport Equipment” sectors. Several industry concentrations exist in the Northwest, Northeast, and West regions.

Figure 13. Map of Industry Concentrations Identified in Pennsylvania

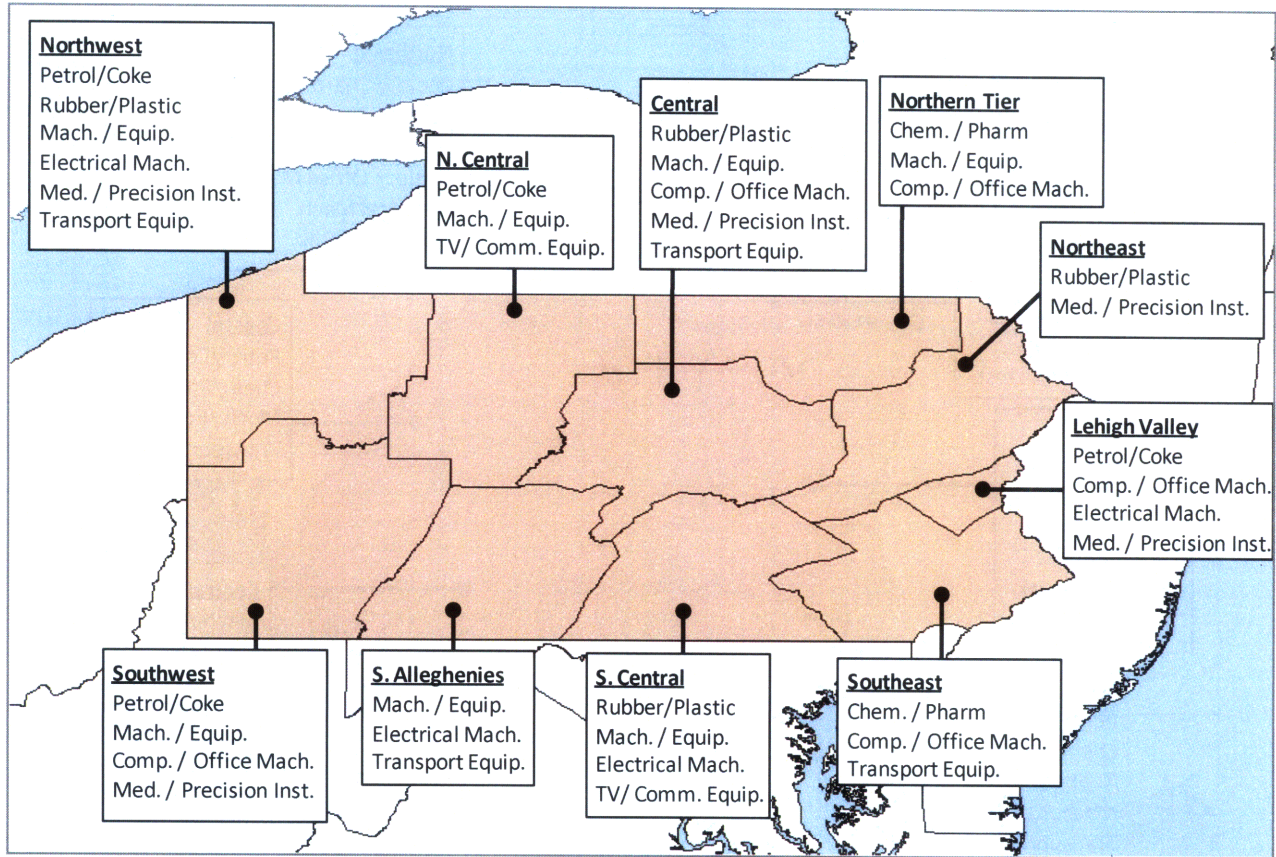


Table 9. Industry Concentrations in Pennsylvania: Median Industry LQ

Region	NW PA	SW PA	N. Central	S. Alleg.	Central	South Central	NE PA	SE PA	Lehigh Valley	North. Tier
DF23: Petrol/Coke	4.0	2.2	2.3	0.8	0.7	0.4	0.3	0.3	1.2	0.4
DG24: Chem/Pharm	0.6	0.5	0.3	0.1	0.6	0.2	1.0	1.7	0.7	1.1
DH25: Rubber/Plastic	2.6	0.9	0.2	0.5	1.5	1.0	1.6	0.8	0.9	0.7
DK29: Mach./Equip	2.3	1.1	1.8	1.4	1.0	1.7	0.5	0.6	0.9	1.5
DL30: Comp./Office	0.0	1.1	0.7	0.1	2.2	0.2	0.5	1.2	1.3	1.6
DL31: Elec. Mach.	1.3	0.8	0.5	1.3	0.9	1.3	0.7	0.5	4.9	0.6
DL32: TV/ Comm.	0.4	0.7	3.9	0.2	0.7	2.1	0.6	1.0	0.6	0.5
DL33: Med., Prec. Instr.	1.0	1.1	0.8	0.6	1.2	0.6	1.7	1.0	1.1	0.0
DM34-5: Transport Equip.	2.9	0.4	0.4	1.4	1.5	0.9	0.6	1.2	0.1	0.8
High Tech	1.7	0.8	1.0	0.9	1.1	1.0	0.9	1.0	1.2	1.0

The state of Pennsylvania is distinct from Georgia and Portugal in that its population is distributed throughout the state. Rather than one large urban center (as with Lisbon and Atlanta), the state has several urban centers that are spread across the corners of the state. Figure 13 and Table 9 show that technological industry in Pennsylvania is highly distributed as well. Fewer

industries are concentrated in the North and Northeast of the state and, on the whole, there is no clear pattern that connects the population density to industrial activity in Pennsylvania.

5.1.2 Higher Education Concentrations

The previous subsection showed the results of the industry concentration measurements that determined how industry sectors are geographically distributed in Portugal, Georgia, and Pennsylvania. My methodology uses a similar location quotient calculation to determine how higher education programs are distributed in these regions. The following tables show the relative concentrations for graduates of universities and university alternatives (polytechnics or community colleges) across the different sectors and regions of interest. As with the industry sectors above, I identified a relative concentration for location quotients greater than 1.0, with the concentration strength increasing with the LQ value. I indicate these relative concentrations and their strengths in Tables 10 through 12 using gradient shading and I provide brief observations for each region. The comparisons between industry and higher education concentrations are presented in the next subsection, 5.1.3.

Table 10 below shows the higher education concentrations in Portugal. The table shows that the high tech sectors of Portuguese education are mostly concentrated in the Norte and Centro regions, with some activity in Algarve and Lisboa. The table indicates a significant degree of overlap between the university and polytechnic programs, especially in the Centro region. The polytechnic graduates show strong concentrations (LQ > 1.5) in a few sectors in the Algarve and

Table 10. Higher Education Concentrations in Portugal: Graduate LQs

Region University (U), Polytechnic (P)	Norte		Algarve		Centro		Lisboa		Alentejo		Açores		Madeira	
	U	P	U	P	U	P	U	P	U	P	U	P	U	P
DF23: Petrol/Coke	1.0	1.0	0.0	0.0	1.2	1.5	0.9	1.0	0.3	0.0	0.0	0.0	0.0	0.0
DG24: Chem/Pharm	1.1	1.1	0.9	0.1	1.1	1.2	0.9	1.1	0.6	0.1	0.0	0.0	0.0	0.2
DH25: Rubber/Plastic	1.0	1.0	0.0	0.0	1.2	1.5	0.9	1.0	0.3	0.0	0.0	0.0	0.0	0.0
DK29: Mach./Equip	1.0	1.0	0.7	1.7	1.0	1.8	1.1	0.6	0.3	0.7	0.3	0.0	0.0	0.0
DL30: Comp./Office	1.0	1.0	0.5	0.9	0.9	1.6	1.2	0.8	0.1	0.6	0.5	0.0	0.8	0.0
DL31: Elec. Mach.	1.2	1.1	0.7	0.0	1.2	1.7	0.8	0.7	0.4	0.4	0.5	0.0	0.0	0.0
DL32: TV/ Comm.	1.2	1.1	0.7	0.0	1.2	1.7	0.8	0.7	0.4	0.4	0.5	0.0	0.0	0.0
DL33: Med., Prec. Instr.	1.1	1.1	0.7	1.9	1.1	1.6	0.9	0.7	0.3	0.2	0.0	0.0	0.0	0.0
DM34-5: Transport Equip.	1.0	1.0	0.7	1.7	1.0	1.8	1.1	0.6	0.3	0.7	0.3	0.0	0.0	0.0
High Tech	1.1	1.1	0.7	1.2	1.1	1.6	1.0	0.8	0.4	0.4	0.9	0.0	1.3	0.0

Centro regions, but the university graduates do not show strong concentrations in any regions. This is not to say that schools are not present in these regions of Portugal; the map of Portuguese HEIs in Figure 3 on page 3232 shows that HEIs are distributed across the country. The data do indicate, though, that universities in Portugal (and polytechnics as well in Alentejo, the Azores, and Madeira) do not show concentrations of graduates in the technology sectors.

Table 11 below shows the concentrations of HEI graduates from different programs in the regions of Georgia and there are two clear differences from the plot of Portuguese concentrations in Table 10. For one, there is little overlap in Georgia between universities and university alternatives. The university graduates in Table 11 appear to be strongly concentrated in the Atlanta region and almost nowhere else, while the community colleges are strongly concentrated in the Northwestern, Western, and Southern regions, and weakly concentrated in the Central and Coastal regions. Secondly, there appear to be trends in the types of courses that the two institution types offer. We can also see that there are three strong concentrations of university courses that fit the Chemical/Pharmaceutical industry, but that the community colleges do not offer many courses in sectors pertaining to Petroleum, Chemicals, or Rubbers / Plastics. Sector DL33, Medical and Precision Instruments, is also only weakly catered to at the community college level. The differences that noted above suggest that the distribution of higher education is very different in the U.S. and Portugal. However, the state of Georgia is not representative of the entire U.S. After looking at the distribution in Pennsylvania on the next page, we will see that this U.S.-Portugal distinction is not really so clear.

Table 11. Higher Education Concentrations in Georgia: Graduate LQs

Region	NW GA		NE GA		Atlanta		West		Central		Coastal		South	
	U	C	U	C	U	C	U	C	U	C	U	C	U	C
DF23: Petrol/Coke	0.4	0.0	0.8	0.0	1.7	0.0	0.3	0.0	0.5	0.0	0.8	0.0	0.1	0.0
DG24: Chem/Pharm	0.2	0.0	1.9	0.5	0.9	0.3	0.2	0.0	1.6	0.0	1.5	0.0	0.0	0.0
DH25: Rubber/Plastic	0.4	0.0	0.8	0.0	1.7	0.0	0.3	0.0	0.5	0.0	0.8	0.0	0.1	0.0
DK29: Mach./Equip	0.3	1.8	0.3	0.6	2.1	0.4	0.4	1.9	0.3	1.5	0.4	1.2	0.1	1.9
DL30: Comp./Office	0.2	2.3	0.2	0.5	2.1	0.8	0.1	1.6	0.5	0.9	0.6	0.9	0.1	1.5
DL31: Elec. Mach.	0.2	1.9	0.4	0.4	2.0	0.8	0.4	1.8	0.4	1.2	0.4	1.1	0.1	1.3
DL32: TV/ Comm.	0.2	1.9	0.4	0.4	2.0	0.8	0.4	1.8	0.4	1.2	0.4	1.1	0.1	1.3
DL33: Med., Prec. Instr.	0.3	0.0	0.7	0.3	1.7	1.0	0.4	1.4	0.5	1.1	0.8	1.0	0.2	1.3
DM34-5: Transport Equip.	0.3	1.8	0.3	0.6	2.1	0.4	0.4	1.9	0.3	1.5	0.4	1.2	0.1	1.9
High Tech	0.3	2.0	0.6	0.5	1.8	0.6	0.3	1.8	0.5	1.3	0.7	1.1	0.1	1.6

Table 12. Higher Education Concentrations in Pennsylvania: Graduate LQs

Region	NW PA		SW PA		S Alleg.		Central		South Central		NE PA		SE PA		Lehigh Valley	
	U	C	U	C	U	C	U	C	U	C	U	C	U	C	U	C
University (U), Comm. College (C)																
DF23: Petrol/Coke	0.0	0.9	1.1	0.0	0.6	0.0	1.6	0.0	0.3	0.5	0.4	0.0	0.8	0.6	2.3	0.0
DG24: Chem/Pharm	1.1	0.5	0.7	0.0	0.4	0.4	0.6	0.0	0.7	0.3	0.4	0.0	1.5	0.4	0.6	0.9
DH25: Rubber/Plastic	0.0	0.9	1.1	0.0	0.6	0.0	1.6	0.0	0.3	0.5	0.4	0.0	0.8	0.6	2.3	0.0
DK29: Mach./Equip	1.2	1.3	1.0	1.1	0.0	0.0	1.9	0.1	0.8	1.7	0.5	0.6	0.7	1.1	1.4	1.2
DL30: Comp./Office	0.7	1.0	1.4	1.0	0.0	0.0	1.1	0.1	0.9	2.0	0.7	0.6	0.8	1.1	1.0	1.8
DL31: Elec. Mach.	1.1	0.9	1.1	1.1	0.0	0.0	1.5	0.1	0.9	2.2	0.6	0.7	0.8	1.1	1.2	1.1
DL32: TV/ Comm.	1.1	0.9	1.1	1.1	0.0	0.0	1.5	0.1	0.9	2.2	0.6	0.7	0.8	1.1	1.2	1.1
DL33: Med., Prec. Instr.	1.3	1.0	0.9	1.1	1.1	0.0	1.3	0.1	0.9	2.3	0.6	0.8	1.0	1.0	1.2	1.2
DM34-5: Transport Equip.	1.2	1.3	1.0	1.1	0.0	0.0	1.9	0.1	0.8	1.7	0.5	0.6	0.7	1.1	1.4	1.2
High Tech	2.0	2.1	1.7	2.1	1.8	2.6	2.4	0.2	1.4	3.8	1.0	1.3	1.6	2.0	2.1	2.6

Note: The North Central and North Tier regions are not shown; they do not contain any HEI concentrations.

Table 12 above shows the location quotients for higher education college graduates in the state of Pennsylvania. The table shows strong university concentrations in the Central region and strong community college concentrations in the South Central region. Like Georgia, Pennsylvania shows little community college activity in the Petroleum, Chemical / Pharmaceutical, and Rubber / Plastics sectors. However, Pennsylvania is unlike Georgia in that its regions show overlaps between community college and university activity, particularly in the NW, SW, and Lehigh Valley regions.

5.1.3 Co-locations of Industry and Higher Education

The previous two sub-sections identified the sectors and regions that show a higher than average concentration of industrial and HEI activity. The intersection of these results identifies the areas that have a *co-location* of industrial and academic activity. This section consolidates the LQ data and identifies regions and sectors with co-locations of industry and higher education. The previous two sub-sections identified relative concentrations where the location quotient for a region was greater than 1.0. The reader should note, though, that many of the concentrations that were identified showed LQs only slightly larger than one. This means that, while these regions have a relative concentration compared to the reference area, many of the concentrations identified were not very strong. Industry and higher education concentrations that persist at higher LQ cutoff values are stronger than those with LQ values marginally above 1.0. To compare the strengths of these concentrations, this section will show how the concentrations

decay as the cutoff value in the LQ calculation is raised above $LQ = 1.0$. This section will also discuss the different patterns that exist for the geographic areas of interest.

Tables 13, 14, and 15 on the next page show the concentrations identified for Portugal, Georgia, and Pennsylvania, respectively. In the table cells, the letters **I**, **U**, and **P/C** indicate where relative concentrations ($LQ > 1.0$) exist for **I**ndustry, **U**niversities, and **P**olytechnics or **C**ommunity Colleges. The letter indicators are shaded according to the gradient scale described above the tables. The indicators in faint grey text represent weak concentrations with an LQ slightly larger than 1.0; those in dark bold text represent very strong regional concentrations, with LQs of 2.0 or larger²⁴. The tables demonstrate the point made in the previous paragraph: there are many instances of slight concentration in the regions of interest, but fewer instances of strong concentration for industries and HEIs.

Looking at the tables one by one, we can pick out a few regional patterns. Table 13 shows that, in Portugal, the concentrations of industry and HEI graduates rarely coincide. The technology industries are clustered in Lisboa and Alentejo, while higher education is clustered in Centro and Algarve (with weak HEI concentrations in the Norte region). Table 14 shows that Georgia has some intersections between industry and community colleges in the West and Northwest regions. There is little industry-HEI overlap for the universities in Atlanta or the industries in Northeastern Georgia, though. Table 15 shows a more mixed situation in Pennsylvania. There are several instances, such as in the Northwest and Lehigh Valley regions, which show strong industry concentrations combined with weak HEI concentrations. The only instance on strong HEI-industry co-location in Pennsylvania is in the TV/Communications sector in the South Central region. This instance and other strong co-locations from the study are summarized after the gradient tables, on page 66.

²⁴ An LQ value of 1.0 for a given sector in a region indicates that the proportion of regional industry in the sector is equal to the reference area's proportion of industry in the sector. A location quotient greater than 2.0 for an industry sector, such as the Electrical Machinery industry in Lisbon, indicates that the industry is highly concentrated in the region – the sector is at least twice as concentrated as it is in the reference area. The reference areas used in this analysis were Portugal, Georgia, and Pennsylvania.

I = concentration of Industry

U = concentration of University graduates

P, C = concentration of non-university graduates (Polytechnics or Community colleges)

LQ Scale						
1.0	1.2	1.4	1.6	1.8	2.0	

Table 13. Co-location of *Portuguese* HEIs and Industry, LQ gradient from 1.0 to 2.0

	Norte	Algarve	Centro	Lisboa	Alentejo	Açores	Madeira
DF23: Petrol/Coke	U P		U P	I	I		
DG24: Chem/Pharm	U P		U P	I P	I		
DH25: Rubber/Plastic	U P		I U P		I		
DK29: Mach./Equip	U P	I P	I U P	I U			
DL30: Comp./Office	I U P			P I U			
DL31: Elec. Mach.	U P		I U P	I	I		
DL32: TV/ Comm.	U P		U P	I			
DL33: Med., Prec. Instr.	U P	P	U P	I			
DM34-5: Transport Equip.	U P	P	I U P	I U	I		
High Tech	U P	P	I U P	I	I		U

Table 14. Co-location of *Georgian* HEIs and Industry, LQ gradient from 1.0 to 2.0

	NW GA	NE GA	Atlanta	West	Central	Coastal	South
DF23: Petrol/Coke			U			I	I
DG24: Chem/Pharm	I	I U			U	I U	I
DH25: Rubber/Plastic	I	I	U	I			I
DK29: Mach./Equip	I C	I	U	I C	I C	I C	I C
DL30: Comp./Office		C I	I U	C			C
DL31: Elec. Mach.	I C	I	U	I C	I C	C	C
DL32: TV/ Comm.		C	I U	I C	C	C	C
DL33: Med., Prec. Instr.		I	I U	I C	C		C
DM34-5: Transport Equip.	I C	I	U	I C	I C	I C	I C
High Tech	I C	I	U	I C	C	I C	I C

Table 15. Co-location of *Pennsylvanian* HEIs and Industry, LQ gradient from 1.0 to 2.0

	NW PA	SW PA	N. Central	S. Alleg.	Central	South Central	NE PA	SE PA	Lehigh Vallev	Northern Tier
DF23: Petrol/Coke	I	I U	I		U				I U	
DG24: Chem/Pharm	U							I U		I
DH25: Rubber/Plastic	I	U			I U	I	I		U	
DK29: Mach./Equip	I U C	I C	I	I	I U	I C		C	U C	I
DL30: Comp./Office		C I U C			I U	C		I C	I C	I
DL31: Elec. Mach.	I U	U C		I	U	I C		C	I U C	
DL32: TV/ Comm.	U	U C	I		U	I C		C	U C	
DL33: Med., Prec. Instr.	I U C	I C		U	I U	C	I	C	I U C	
DM34-5: Transport Equip.	I U C	C		I	I U	C		I C	U C	
High Tech	I U C	U C		U C	I U	U C	C	U C	I U C	

To conclude the co-location analysis, Table 16 below lists all the instances of strong co-location between industry and higher education that were identified in this analysis. “Strong co-location” is defined here when both the industry and higher education have LQs greater than 1.5. Three observations from Table 16 are particularly striking. First, Portugal has no instances of strong co-location in any regions. Second, for Georgia and Pennsylvania, there are twice as many strong co-locations identified for university alternatives as for universities. Third, there is a distinction between the industry sectors that co-locate with university courses and those that co-locate with courses at university alternatives. Three out of four co-locations with universities are in the Chemical/Pharmaceutical sector; and six out of eight co-locations with university alternatives are in sectors pertaining to machinery or equipment. This last finding ties in with the literature, which found inter-industry differences in the relationship between universities and industrial innovation. These studies (GUIRR (Government University Industry Research Roundtable) 1991) (Mansfield 1991) (Cohen, Nelson et al. 2002) found that the biomedical and pharmaceutical sectors are unique in that university research affects industrial innovation more significantly and directly than in other sectors. While we cannot conclude anything about innovation effects, the co-location results do support the idea that the Chemical/Pharmaceutical industry sector tends to co-locate with universities more than other sectors in Georgia and Pennsylvania.

Table 16. Instances of Strong ($LQ > 1.5$) Co-location between Industry and HEIs

Co-location between Industry and Universities		
Portugal	(none)	
Georgia	Northeast	Chemical/Pharmaceutical
	Coastal	Chemical/Pharmaceutical
Pennsylvania	Central	Transport/Equipment
	Southeast	Chemical/Pharmaceutical
Co-location between Industry and University Alternatives		
Portugal	(none)	
Georgia	Northwest	Electrical Machinery
	West	Electrical Machinery, TV/Communications, Transport Equipment
	Central	Machinery/Equipment
	South	Transport Equipment
Pennsylvania	South Central	TV/Communications, Machinery/Equipment

5.2 Regression Results

To connect the results of my co-location analysis with innovation activity, I regressed the Portuguese location quotients presented in the previous section with innovation data from the Community Innovation Survey²⁵. The table below displays the results of the Ordinary Least Squares regression of the innovation production function described in Section 4.2.6. The dependent variable I is the percentage of firms that reported innovation activity in the period 2002-04. C is the shared location quotient of HEIs and industry and it is used to describe the co-location between HEIs and industry. The vector Z controls for regional attributes that are believed to contribute to innovation activity. Z contains figures for population density, GDP per capita, and R&D expenditure.

Table 17. Estimation of Innovative Activity*, dependent variable: $\ln I$

Variable		OLS estimation equation (2)		
$\ln C_{Univ}$	Co-location of universities and industry	0.0608 (0.162)	--	--
$\ln C_{Poly}$	Co-location of universities and industry	--	0.0391 (0.153)	--
$\ln Z_1$	Population density	-0.107 (0.170)	-0.0906 (0.159)	-0.0792 (0.151)
$\ln Z_2$	GDP per capita	1.47 (0.780)	1.44 (0.775)	1.44 (0.763)
$\ln Z_3$	R&D Expenditure	-0.200 (0.116)	-0.197 (0.119)	-0.205 (0.113)
R^2		0.237	0.235	0.234

* Standard error values are given in parenthesis

The results in Table 17 show low R^2 values and high error values, indicating that the variables C and Z are poor predictors of the variable I . When the Z vector of regional attributes was regressed without the co-location values (in the third column above), the error values were over twice the co-efficient values. Because the variables in the Z vector are expected to be good predictors of innovation activity, this suggests that the innovation survey measurement I is not useful for measuring innovation activity. In the following chapter, I recommend a way to improve the innovation measurement potential of the Community Innovation Survey.

²⁵ The Georgia Manufacturing Survey does not present regional results by industry sector, so it was omitted from the regression.

5.3 Interpretation and Analysis

To interpret the results presented in Sections 5.1 and 5.2, I would like to first recall the objective of this analysis, which was put forth in the first section of Chapter 4: Methodology. The goal of this analysis was to identify where concentrations of industry coincide with concentrations of higher education and to test the following questions: (1) For the regions of Portugal and the U.S. state of Georgia, is the spatial distribution of industry similar to the spatial distribution of higher education graduates? (2) Is this relationship different for graduates from universities and graduates from university alternatives? (3) Is there a detectable correlation between HEI-industry co-location and firms' innovation?

The results of the co-location analysis indicate that, in Portugal, the technology industries do not coincide with the technology courses in higher education. Portugal's technology industries are strongly concentrated in the Lisboa and Alentejo regions where there is little higher education concentration. On the other hand, Georgia has several strong co-concentrations at the $LQ = 1.5$ cutoff value. Industry and universities co-locate more frequently for the Chemical / Pharmaceutical sector than for other technology sectors. Additionally, Western Georgia shows significant overlap between industry and community college courses. The results in Pennsylvania are mixed. It is clear that the HEIs are concentrated in six of the ten sub-regions, but the technology industries in Pennsylvania are scattered across the state in an almost random fashion.

The second question of this analysis regards whether the co-location results differ for universities and university alternatives. The results for Portugal show little difference between the two institution types. Most of the cells with academic concentrations in Portugal's co-location matrix (Table 13) show sectoral concentrations for *both* universities and polytechnics, indicating a large regional overlap in the institutional offerings. On the other hand, the regions of Georgia and Pennsylvania showed several instances of HEI-industry co-locations for universities and community colleges. This suggests that the academic sector is more aligned with regional industry needs in these two states. The results also showed different co-location tendencies for university and community college offerings. As Section 5.1.3 pointed out, the university-industry co-locations tended to occur in the Chemical / Pharmaceutical sector and the community college-industry co-locations tended to occur in sectors related to Machinery and Equipment. In order to

more closely examine why the locational analysis indicates such weak correlation in Portugal (relative to the two reference U.S. states), it is worthwhile to look for other differences that might cause this. A likely, though speculative, candidate is the degree of regional autonomy in Portugal's education system. The higher education system in Portugal is controlled at a national level, which makes it less likely to adapt to local needs, whereas in the U.S. states, local regions have a larger role in determining the objectives of HEIs.

The results of this analysis do not adequately address the third question, which concerns the effects of HEI-industry co-location on industry innovation. The regression results in Section 5.2 do not show a correlation between co-locations and innovation. However, the input data used in this econometric analysis has several flaws. For one, the sub-regions of Portugal do not exhibit any strong co-locations of industry and higher education. With only weak co-locations to analyze, it is unsurprising that the regression analysis failed to identify a strong signal regarding the effects of co-location. Secondly, the Community Innovation Survey data used in the regression analysis does not measure the total innovation output of a region; the data only captures the number of firms that claim to innovate. It is again unsurprising that a weak indicator such as this yields inconclusive results in a regression analysis. Section 6.3 below suggests possible improvements to the innovation survey indicators which could lead to a more meaningful regression analysis.

6 Conclusions

This final chapter of my thesis will offer conclusions based on my background research and the results of my co-location and regression analyses. In the previous section, I presented an interpretation of my analytical results. The following sections will take the analysis one step further, by relating these results to the structural context of the Portuguese and U.S. higher education systems. This chapter presents several caveats that accompany these conclusions and offers policy recommendations based on my interpretation of the results.

6.1 Contextual Analysis

6.1.1 Education Structure

In both the U.S. and Portugal, the stated goals of the university alternatives are to serve local industry, increase regional economic development, and provide vocational career training. One major difference between the higher education systems in the U.S. and Portugal is that the Portuguese system is centrally controlled, while education priorities in the U.S. are determined at the local and state level²⁶. This structural difference could be a root cause of the different co-location results in the U.S. and Portugal. It is likely that local and state officials are more attuned to regional labor needs and are thus better positioned to guide any institutions wishing to serve those needs. The results in Section 5.1.3 showed (1) that the U.S. states of Georgia and Pennsylvania exhibited more instances of HEI-industry co-locations than the nation of Portugal, and (2) that university alternatives showed a greater co-location tendency than universities. It is possible that the U.S. regions showed more HEI-industry co-locations because the local and state authorities are subject to influence from local industry. Community colleges in the U.S. receive a larger portion of their budget from local authorities than universities do, which may explain why the community colleges showed more co-location instances than universities.

6.1.2 Cultural Context

It is important to note the different cultural contexts in the U.S. and Portugal. On the whole, Americans are typically more geographically mobile than Portuguese. American students bound for higher education often leave their hometowns to pursue their schooling, and Americans often

²⁶ Portuguese law requires *some* local participation on the governance boards of polytechnic institutions. However, the funding of polytechnic institutions is (for the most part) nationally coordinated and new course offerings must be approved by the national education ministry.

begin their careers in different locations than where they were raised. In contrast, the Portuguese tend not to stray too far from home. Many students receive their higher education and begin their careers in the same town in which they were raised. This contrast leads to a remarkable difference in the higher education concentration tendencies of the U.S. and Portugal. The results in Table 13 show that Portugal has few strong concentrations in the technical sectors of higher education, and no concentrations with $LQ > 2.0$. This means that, rather than being concentrated in a few select regions, the nation's technical programs are spread fairly evenly across Portugal. The result of this distribution is that Portuguese students need not travel far to pursue their field of choice. Meanwhile, Tables 14 and 15 show that higher education in Georgia and Pennsylvania is more polarized. These states show several strong concentrations ($LQ > 2.0$) for both universities and community colleges. The HEIs are not so evenly spread across these states, and it is perhaps because of the American students' tendency to leave home and travel to school.

6.1.3 Alignment with Findings from the Literature

Several studies in the supporting literature found knowledge spillover effects resulting from proximity between research institutions and industry. Studies in the literature (Mansfield 1991) (Cohen, Nelson et al. 2002) also concluded that the biomedical and pharmaceutical sectors more closely aligned than other sectors with university research. The results from my econometric regression, which attempted to measure spillover effects, were inconclusive. The findings from my co-location analysis were consistent with the literature, though; I found that the research-intensive pharmaceutical sector tends to align geographically with the HEIs which conduct research: universities. Additionally, my background research quoted several researchers who noted that Portugal's polytechnics are not firmly committed to collaboration with regional industry and that their priorities often tend more towards national concerns. This finding is consistent with the lack of HEI-industry co-locations that I identified in Portugal.

6.2 Caveats

I presented the limitations to my analytical method in Section 4.3. Because of these limitations, I must present my conclusions with several caveats, which are described in this section. First of all, my analysis included data describing graduates from higher education institutions and it used this graduate data as a proxy for the production of human capital with training relevant to the sectors of interest. All of the regions of interest possess research centers that are independent of

academic institutions, but my analysis did not consider non-academic institutions. It is possible that firms would choose to locate near these research centers rather than near academic research institutions. My analysis neglects co-locations of industry and non-academic research.

In this analysis, I used the Location Quotient measurement to examine co-locations. The LQ measurement is useful for identifying relative concentrations and it detects which sectors show a higher-than-average concentration in a given region. The LQ measurement is a regional analysis tool that is used to identify sectors that are particularly strong in a given geographical area. However, as I explained in my description of the LQ calculation in Section 4.2.5, the LQ measures each given sector against the total industry activity in the region. This measurement can become distorted if the region of interest is either oversaturated with or devoid of activity. I attempted to prevent this sort of distortion in my analysis by flagging and removing regions with particularly low levels of total activity. However, some error is inevitable.

In Section 5.1.3, I listed the regions in which my analysis showed strong co-locations of industry and HEIs. This existence of co-locations does not prove that there is any interaction between industry and HEIs in these instances. The literature on the knowledge spillovers concludes that proximity between industry and higher education increases the likelihood of knowledge spillovers²⁷. However, proximity alone does not guarantee that spillovers will occur. The reader should bear in mind that the sub-regions used in this analysis are quite large – up to 100 miles (160 km) wide and 250 miles (400 km) long. Therefore, it is very possible that, in some of the co-location cases, the detected concentrations of industries and HEIs do not interact with one another. If industry data at a finer geographic resolution became publicly available, then it would be possible to search for more meaningful co-locations on a smaller geographic scale.

The literature on firm location choices states that the proximity to higher education institutions is one of the factors that businesses consider when deciding where to locate. As described in Section 2.4.2, the converse is assumed to be true as well. That is, I would assume that educational administrators who have the stated goal of serving local industry would choose to

²⁷ In this sense, it would seem like Georgia and Pennsylvania are more likely to exhibit knowledge spillovers, since they show more strong co-locations than Portugal.

locate HEIs near the industries they plan to serve²⁸. However, there are a number of other factors that come into play in selecting locations and course offerings. Among these factors are: the availability of inexpensive real estate, the availability of qualified labor, the proximity to resources (especially for the Petroleum/Coke sector), and the proximity to shipping channels, local tax incentives, political factors, etc. In short, the proximity to higher education institutions (or the possibility of cooperation between institutions in similar sectors) is but one of a long list of considerations when firms decide where to locate.

6.3 Policy Recommendations

The analysis above showed that institutions supported by regional funding (i.e. community colleges in Georgia and Pennsylvania) were more likely to co-locate with industry. In theory, this makes sense: we can expect that institutions will serve the committees that control the purse strings. Currently, the education ministry in Portugal attempts to create regional accountability at polytechnics by requiring that local industry participate in the institutions' steering committees, but the bulk of the HEI funding still comes from the national government. Thus, it is perhaps unsurprisingly that Portugal's HEIs, which are primarily organized and funded at the national level, exhibit very weak co-location with industry. If Portugal truly wishes to align its polytechnic institutions with regional economic development, it would be wise for the national government to give its regions more autonomy to guide and fund the higher education activity within their regional boundaries. These funds could still be sourced from the federal treasury; with regional disbursement used as a means to create regional accountability. However, having some of the funds actually raised from local taxes is an idea that should also be considered.

It is not reasonable for the Portuguese government to mandate a geographic reorganization of the higher education or industry sectors. However, the demographic trends discussed in Section 3.2.2 indicate that some restructuring is inevitable in the higher education sector. The number of students entering higher education in Portugal is expected to decline through the year 2010 and education analysts already predict that the country will need to close or consolidate a number of HEIs. While this is an unfortunate outcome for institutions that face closure, it represents an opportunity for the education ministry to address the founding principles of the polytechnic sector and align polytechnics closer to regional industry priorities. As a start, the education

²⁸ Alternatively, one could assume that institutions which are already rooted would tailor the courses they offer to be relevant to local industries.

ministry could orchestrate the consolidation of HEIs such that technical programs are located close to industry the industries they serve. For instance, the concentration analysis in this thesis showed that the Alentejo region of Portugal has strong concentrations in the Petroleum/Coke and Transportation Equipment industry sectors, but that Alentejo has no concentration of technical higher education courses. If the ministry chooses to consolidate any HEIs with courses relevant to these industries, they may do well by transferring these programs to the Alentejo region, to engender an industry-academic co-location. Similarly, the Lisboa region has strong industry concentrations (but no higher education concentration) in three sectors: Electrical Machinery, Medical and Precision Equipment, and Television/Communications. Consolidating HEI programs for these sectors in Lisboa would increase the opportunities for interaction between industry and academia²⁹.

My final recommendation concerns the collection of innovation survey statistics. In this thesis, I used data from the fourth Community Innovation Survey, which intends to quantify regional innovation activity. Currently, the survey asks firm managers a yes/no question: “Has your firm introduced a new product/process in the [survey time period]?” This phrasing does not allow the survey to distinguish between firms that are extremely innovative and firms that are only marginally innovative. I believe that the survey questionnaire would be greatly improved if it attempted to capture the magnitude of innovation activity within individual firms. The question above could be revised to ask: “*How many* new products/processes has your firm introduced in the [survey time period]?” or “What fraction of your revenue is derived from products introduced in the period?” This revision may place an added burden on survey respondents, but it would make the CIS results more meaningful to researchers studying innovation³⁰. While Portugal does not have the authority to change the CIS questionnaire that is administered in other countries, it does have the authority to add supplemental questions to its own innovation survey. Increasing the quantitative nature of the survey would make the survey results more suitable for econometric analyses, such as the one attempted in Section 5.2.

²⁹ This thesis has not presented explicit evidence to show that a geographic alignment such as this would increase the regional potential for innovation. However, the literature on knowledge spillovers indicates that spillovers from research tend to increase with geographic proximity.

³⁰ A revision such as this would still not fix the problems of interpretation and self-selection (discussed in Section 4.3), which are inherent to survey-based indicators.

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Appendix A: Complete Regression Data and Results

CL_Univ, CL_Poly = Location quotient for co-location of universities / polytechs with industry
 GERD = Gross Expenditure on Research and Development, in Euros

Region Name	NUTS Region Code	NACE Industry Code	CIS-4: % of firms that innovate	CL_Univ	CL_Poly	Population Density	GDP per capita	GERD
Norte	PT11	DF23	*	0.7	0.7	172.9	10,681	166
Centro	PT16	DF23	*	0.0	0.0	83.3	11,070	161
Lisboa	PT17	DF23	*	0.9	1.0	942.8	18,614	564
Alentejo	PT18	DF23	*	0.3	0.0	24.4	11,870	102
Norte	PT11	DG24	*	0.5	0.5	172.9	10,681	166
Centro	PT16	DG24	*	0.7	0.7	83.3	11,070	161
Lisboa	PT17	DG24	*	0.9	1.1	942.8	18,614	564
Alentejo	PT18	DG24	*	0.6	0.1	24.4	11,870	102
Norte	PT11	DH25	*	0.9	0.9	172.9	10,681	166
Algarve	PT15	DH25	*	0.0	0.0	79.1	13,890	14
Centro	PT16	DH25	*	1.2	1.4	83.3	11,070	161
Lisboa	PT17	DH25	*	0.8	0.8	942.8	18,614	564
Alentejo	PT18	DH25	*	0.3	0.0	24.4	11,870	102
Norte	PT11	DK29	*	0.8	0.8	172.9	10,681	166
Algarve	PT15	DK29	*	0.7	1.1	79.1	13,890	14
Centro	PT16	DK29	*	1.0	1.4	83.3	11,070	161
Lisboa	PT17	DK29	*	1.1	0.6	942.8	18,614	564
Alentejo	PT18	DK29	*	0.3	0.6	24.4	11,870	102
Madeira	PT30	DK29	*	0.0	0.0	290.8	16,324	11
Norte	PT11	DL32	*	0.7	0.7	172.9	10,681	166
Algarve	PT15	DL32	*	0.1	0.0	79.1	13,890	14
Centro	PT16	DL32	*	0.3	0.3	83.3	11,070	161
Lisboa	PT17	DL32	*	0.8	0.7	942.8	18,614	564
Alentejo	PT18	DL32	*	0.4	0.4	24.4	11,870	102
Norte	PT11	DL33	*	0.9	0.9	172.9	10,681	166
Algarve	PT15	DL33	*	0.7	0.9	79.1	13,890	14
Centro	PT16	DL33	*	0.5	0.5	83.3	11,070	161
Lisboa	PT17	DL33	*	0.9	0.7	942.8	18,614	564
Alentejo	PT18	DL33	*	0.1	0.1	24.4	11,870	102
Norte	PT11	DM34-35	*	0.6	0.6	172.9	10,681	166
Algarve	PT15	DM34-35	*	0.5	0.5	79.1	13,890	14
Centro	PT16	DM34-35	*	1.0	1.3	83.3	11,070	161
Lisboa	PT17	DM34-35	*	1.1	0.6	942.8	18,614	564
Alentejo	PT18	DM34-35	*	0.3	0.7	24.4	11,870	102

* Figure removed for purposes of confidentiality.

Appendix B: Regional Constructed Variables

The table below presents a collection of regional measurements for the regions included in the econometric regression analysis. These statistics were collected from the Eurostat statistics agency and are meant to capture the regional variation of several factors that contribute to innovation. The inclusion of this vector of variables in the econometric analysis is meant to control for the effects of these variables on innovation creation.

Table 18. Constructed Variable of Regional Characteristics for Portugal's Regions³¹

Constructed variable - Year for all statistics is 2002

NUTS		Pop. Density		Total	GDP, million	GERD, million	Total EPO Patent
Code	Region Name	(people/km ²)	Population	Employment, all sectors	Euros	Euros	Applications
PT	Portugal	112.8	10,368,400	5,151,200	135,434	1,029	49.1
PT11	Norte	172.9	3,679,700	1,781,300	38,917	166	18.5
PT15	Algarve	79.1	394,700	193,900	5,429	14	0.6
PT16	Centro	83.3	2,347,100	1,242,100	25,727	161	10.9
PT17	Lisboa	942.8	2,700,700	1,390,000	49,779	564	16.0
PT18	Alentejo	24.4	767,300	316,200	9,019	102	1.4
PT20	R.A. dos Açores	102.6	238,200	100,700	2,672	10	0.0
PT30	R.A. da Madeira	290.8	240,800	117,900	3,892	11	1.7

³¹ Eurostat (2008). General and Regional Statistics, Eurostat, Statistical Office of the European Communities.