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Timothy Champion Ford
University of New Hampshire, Durham

ESSAYS ON FOREIGN DIRECT INVESTMENT AND GROWTH IN THE UNITED STATES

by

TIMOTHY C. FORD

B.A. Tufts University

M.B.A., Bentley College

M.A.,Economics, University of New Hampshire

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This dissertation has been examined and approved.

Co-Chair: Bruce T. Elmslie
Professor of Economics

Co-Chair: Jonathan C. Rork
Assistant Professor of Economics, Vassar College

Karen Smith Conway
Associate Professor of Economics

Ju-Chin Huang
Associate Professor of Economics

Michael D. Goldberg
Associate Professor of Economics

Lewis S. Davis
Visiting Assistant Professor of Economics, Smith College

Date: 12/19/02

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ABSTRACT

ESSAYS ON FOREIGN DIRECT INVESTMENT AND GROWTH IN THE UNITED STSTES

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The period between 1978 and 1997 was characterized by a major influx of foreign direct investment (FDI) to the United States. In 1997, foreign controlled firms accounted for 6.3 percent of US GDP, 4.9 percent of non-bank employment, 20 percent of US exports of goods, 30 percent of US imports of goods, and 12 percent of firm R&D. However, due to data limitations, previous research has examined the impact of FDI on growth only at the country level. By constructing a new stock measure of FDI—the employment measure— I am able to disaggregate FDI across states. This allows an examination of the impact of FDI on growth at the state level. Because spillovers tend to be local in nature, such a focus gives a better understanding of the impact FDI can have in the growth process. Furthermore, because ownership should

be conceptualized as an on-going relationship, this new stock measure, which proxies for a continuing flow of benefits (information, technology, know-how and etc.) from the source to the host economy, captures these benefits better than those based on one time investment flows. Drawing on ideas present in the areas of economic growth, international trade, knowledge spillovers, regional science, and the multinational firm, my dissertation examines the impact of foreign direct investment (FDI) at the state level.

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Preface

The first essay of this dissertation represents the first investigation into the welfare effects of foreign owned firms relative to domestically owned firms at the state level. While foreign firms bring the immediate benefit of high-paying jobs, very little is known about the long-term effects of foreign firms on the states in which they locate. Empirical results, motivated by a theoretical model of endogenous growth, demonstrate that workers employed by a foreign firm impact productivity growth more than workers employed by a domestic firm but only when the host-state has a minimum threshold level of human capital. An economic growth framework is applicable to the study of such welfare effects because of the strong correlation between growth and a broad set of basic social indicators including poverty rates, infant mortality, life expectancy, and literacy rates. Additionally, though not the main focus of this essay, empirical results match the theoretical model's prediction of scale effects. Given the amount of effort that has been expended to resolve this problem, this finding has the potential to be of great importance to the growth literature. Overall, the essay reaffirms the impact of education on productivity while finding that the majority of states most active in the recruitment of FDI, those located in the American South, fall short of the minimum threshold level of human capital needed to justify their expenditures to recruit foreign firms.

While essay one asserts that FDI is more productive than domestic investment in the presence of a minimum level of human capital, the question of whether the source country of FDI matters remains unanswered. It has long been surmised that firms controlled by different countries may have unequal effects due to a number of factors including the quality of jobs being exported by the source country and the degree to which foreign firms differ from domestic firms. While results do support differences in the growth effects of FDI across source countries, these differences are not in-line with the public's belief that certain countries have a tendency to export low-skilled and low-paying jobs in order to access US markets. Consistent with ideas presented in the work of economic historians, results demonstrate that FDI's effect on growth depends on the relative differences between the endowments of the host and source economy. The implication of this result is that there is a cost to the transfer of technology and, if technology is created to substitute for scarce resources, this cost is greater the more dissimilar are endowments. This essay highlights a role for state policy officials in the recruitment of foreign firms with technology that is compatible (as measured by endowments of capital and labor) to the state in question.

If foreign firms bring increased industry and technological know-how, management skills, information, and etc., and if spillovers tend to be local in nature as supported by the literature, then one would expect geographic proximity to play major role. In fact, Adam Smith contemplated a role in economics for geographic distance (in transport costs) way back in 1776. Yet, to date, the profession has been slow to incorporate space into economic analysis. Essay Three explores the role of distance in economic growth, first as it relates to the idea of convergence, then as it specifically relates to FDI and growth. For example, it is very likely that a bordering state, like Tennessee, may be blessed with a positive externality from Alabama's recruitment of FDI. Furthermore, it is also possible that factors besides geographic distance, like industry make-up, may play a role in the determination of the ultimate benefactors of FDI. For example, a state like Michigan that produces cars may be affected (positively or negatively) regardless of distance, by the recruitment of a foreign car company in Alabama. Results, however, are quite surprising. Findings suggest negative spillovers result from increased foreign control of a neighboring state. Although more research is needed in this area, possible explanations are business stealing effects and/or the fleeing of highly educated workers to bordering states (the so called "brain drain").

Chapter 1

On Stocks, Flows, and the Real Economic Significance of Foreign Direct Investment: Does Control of Production Matter to Economic Growth?

> What we seek to measure is the extent to which foreign firms and individuals control US production, yet it is not easy to define precisely either the nationality of a firm or what constitutes control.
>
> –Graham and Krugman, 1991, p.7

1.1 Introduction

Since the late 1970's the presence of foreign firms in the United States economy has increased dramatically. According to data collected by the Bureau of Economic Analysis (BEA) and published by Zeile (1999), employment by foreign firms in the US has increased three times, GDP attributed to foreign firms has increased nine times, and total assets of foreign firms in the US has increased twenty times from 1978 to 1997. In 1997, the most recent year for which data is available, 6.3% ($384.9 billion worth) of the output of the world's largest economy was produced by firms controlled by non-US entities.

While the sheer volume of foreign participation in the US economy certainly begs for an inquiry into its economic effects, a more publicized trend concerns the recruitment of foreign firms by state and local government agencies. Although individual states, especially those located in the American South, have competed for business for a number of years, competition for foreign direct investment (FDI) seems to have become especially intense. For example, in 1978 Pennsylvania paid $71 million for a Volkswagen factory that eventually closed before 1988. Kentucky won the bidding for a Toyota plant in 1985 for $150 million. In 1992 South Carolina paid $100,000 per job ($150 million total) for a BMW plant. Alabama's 1993 wooing of Mercedes-Benz for $253 million or $168,000 for each of the 1,500 newly created jobs prompted the following responses[1]:

[1]As reported by Donald W. Nauss in the *Los Angeles Times*, October 1, 1993, part D, page 1.

"It looks like they gave them everything but the Crimson Tide (the University of Alabama's football team)."

–George Autry, head of a group representing rival North Carolina.

"They went crazy. This is lunatic stuff"

–Joel Kotkin, a Los Angeles economic analyst who has followed various competitions among states for corporate investment.

Foreign firms bring the promise of increased employment at higher than average wages. However, just by looking at the examples above one can see that the immediate impact has the potential to affect only a small portion of the population. Alabama has a population in excess of 4 million; the probability of gaining one of the 1,500 prized Mercedes jobs is akin to winning the lottery. In order to justify such expenditures, gains must extend to a larger portion of the state's population.

Despite major attention in the popular press and heated debates in the halls of Congress, there has yet to be an empirical examination of the welfare effects of foreign direct investment in the United States. The reason for this void, it seems, is the absence of state-level data on flows of inward FDI. This problem, however, is easily avoided by viewing FDI as a stock rather than a flow. In addition to solving the FDI data problem, this distinction more accurately captures the transfer of resources that occurs between a foreign parent and its domestic host.

Utilizing a new stock measure of FDI—the employment measure—that directly measures foreign control of domestic production (FCDP), this paper represents the first empirical examination of the growth effects of foreign owned firms relative

column 5.

to domestically owned firms in the United States. Empirical results, motivated by a theoretical model of endogenous growth, demonstrate that states with a higher FCDP grow faster per worker than states with a lower FCDP, but only when the host-state has a minimum level of human capital.[2]

The rest of the paper is organized as follows: Section 3.2 gives a discussion of FDI and how it is measured. Section 3.3 briefly reviews the relevant literature. Section 1.4 develops a theoretical framework of FDI on growth. Section 1.5 describes the data and the econometric methods. Section 3.4 examines the results. Section 3.5 concludes.

1.2 Foreign Direct Investment: It's All About Control

To this point, empirical studies analyzing the growth effects of FDI have relied upon flow data (usually expressed as a percentage of domestic GDP). Although economists have been conditioned to think of investment as a flow, such a measure makes it difficult to determine the total impact of FDI. This is due to a recurring theme in the literature that emphasizes FDI as a conduit for the transfer of knowledge based assets. While flow measurements will capture a portion of the transfer of these assets

[2]Additionally, though not the main focus of this paper, empirical results match theoretical predictions of scale effects. Given the amount of human capital that has been expended in order to "fix" this problem, this finding has the potential to be of great importance to the growth literature.

that occur in the beginning stages of the parent-subsidiary relationship, the use of flow data implicitly assumes that any FDI growth effects are limited to the period in which the investment is made. Foreign parents transfer a wealth of assets not capable of being priced and not constricted to the time period in which the initial investment takes place. These may include, but are not limited to, industry and technological know-how, management skills, and market information. A one-time investment by a foreign firm tells nothing about the subsequent flow of benefits that are likely to occur as the foreign firm participates in operations of the domestic firm. Further, the flow of benefits may or may not be reflected in the value of the investment. Consequently, a stock measure is best suited to capturing the immeasurable and infinitely lived flow of these intangibles. While the use of flow data may result in empirical estimates that are correct in sign and significance due to the relationship that a flow plays in building FDI stock, the use of flow data is not consistent with the theory of FDI and the coefficients are unlikely to be of the proper magnitude.[3]

The US Department of Commerce considers an investment as direct when any foreign entity (whether a person, firm, partnership, government, or etc.) owns or controls at least 10 percent of a US firm[4]. This 10 percent threshold is considered evidence that the foreign entity has "a lasting interest in or a degree of influence over management". (Quijano, 1990, p.29) While 10 percent may not seem sufficient

[3]The use of flow measures is most likely not due to choice but to data availability. For example, Borensztein, DeGregorio and Lee (1998) express their inability to construct a stock measure from the flow data available to them.

[4]At this point the US firm is considered a US affiliate of the foreign firm controlling it.

to guarantee a foreign entity's control over the operations of the US firm. Graham and Krugman (1991) cite that on average a foreign entity controls 78.8 percent of the domestic firm's equity. Such a large majority makes the 10 percent threshold irrelevant. Further, the authors claim that the Bureau of Economic Analysis, the agency responsible for collecting data on foreign direct investment in the US, has found little change even after raising this threshold to as high as 50 percent. The point is that FDI is important to the extent that it measures foreign control of domestic production (FCDP). Though FDI flows contribute to the stock of FDI over time it cannot measure control.

Of the data available for constructing a stock measure of FDI for the US economy, Graham and Krugman (1991) favor using non-bank employment in US affiliates of foreign firms—the employment measure. This is due to the possibility of measurement error that is associated with the other common measures. The most common measure, the balance of payments-based measure of the cumulative stock of FDI in the US, is calculated at book value and most likely understates current market values of foreign owners' equity. The other common measure is total assets under control of foreign owned firms. The asset measure, as it is called, is dominated by the assets of financial firms that have no bearing on production.

Using non-bank employment in the US affiliates of foreign firms, a stock ratio is formed by expressing the employment measure as a percentage of total employment in the economy. This ratio will then be a measure of foreign control of the domestic economy. This stock-variable will proxy for the flow of over any time period.

Non-bank employment is used mainly because foreign banks do not seem to act in a similar way as other foreign firms. According to Graham and Krugman (1991) foreign banks in the US are dominated by the presence of Japanese firms. And though there are many theories as to the reason for this disproportionate presence, foreign banks are not well behaved in terms of the theory of industrial organization. As such, their inclusion is likely to bias results. Figure 1 displays the rise of FDI in the 48 continuous United States using the employment measure. Of importance is the synchronic movement of the employment measure of FDI with the percent of United States GDP produced by foreign firms. This further justifies the employment measure as an accurate measure of foreign control of the domestic economy.

1.3 Relevant Literature

The endogenous growth literature emerged as a result of the inadequacies of the neoclassical growth models of Solow(1956) and Swan (1956) and later Cass (1965) and Koopmans (1965) to explain growth by factors determined inside the models. The models predict that in the steady state, growth is determined solely by the rate of technological progress which is exogenously determined.

Romer (1986) kicked off the modern revival of economic growth by allowing for knowledge spillovers that were the unintended result of investment decisions made in a perfectly competitive market. Such externalities increased the stock of knowledge in proportion to the stock of capital, resulting in an aggregate production function void of diminishing returns. Later, models emerged which linked the evolution of technology through the intentional decisions of firms to undertake research and development in the quest for monopoly profits. These include the horizontal technological progress models of Romer (1987) and Romer (1990) and the vertical technological progress models of creative destruction of Aghion and Howitt (1992).

The key to generating endogenous growth in the models of horizontal and vertical technological innovation reside in the assumptions made concerning the properties of the technology and knowledge created by research and development. Grossman and Helpman (1991) show that if the knowledge and technology created is assumed to be a private good, growth in the model eventually stops. However, if the knowledge created by research and development is nonrival and at least partially nonexcludable, the benefits of the increased knowledge can be spread over many and endogenous growth occurs.

Jaffe(1986) supports the existence of knowledge spillovers. He finds that firms who perform research in an area dense with other high research firms gain more patents per dollar of research and development as well as higher returns to investment in research and development. Further, Jaffee, Trajtenberg and Henderson (1993) show through the use of patent data that knowledge spillovers tend to occur not only at the country level but more specifically spillovers tend to occur at the state and SMSA level and spread slowly over time.

Work in the area of international trade has established links between the degree of openness of an economy and its rate of growth via the diffusion of technology and knowledge[5]. Specifically, Grossman and Helpman (1991) state:

> ...the most important benefit to a country from participating in the international economy might be the access that such integration affords to the knowledge base in existence in the world at large. Countries that trade in world markets invariably learn a great deal about innovative products and about the novel methods that are being used to produce older goods. While it is true that agents in an economically isolated country might also acquire some such information by reading professional journals, speaking to foreign experts, or inspecting prototype products, it seems that the contacts that develop through commercial interaction play an important part in the international exchange of information and ideas. At the least participation in world markets would seem to accelerate greatly a country's acquisition of foreign knowledge. (p. 238)

If such growth effects are present in the trading of goods and services across economies, one would expect at least as strong an effect from the foreign production of the goods in the domestic economy. For example, if we are to believe that technology transfer occurs through a process of reverse engineering, the presence of multinational corporations should allow for technology transfer through learning by watching. By participating in the production process learning is accelerated. Employees can more easily make innovations to the products, capital, and processes. This idea is best expressed by Findlay (1978):

> A major role in the diffusion of new technology in recent times has been played by the international corporations. While the "book of blueprints" in some abstract sense may be open to the world as a whole, even if one

[5]See Edwards (1998).

> may have to pay a stiff price to look at some of the pages, new technology generally requires demonstration in the context of the local environment before it can be transferred effectively, and it is in this connection that the overseas production of major world corporations with their headquarters in the advanced countries has such a vital part to play. (pp. 1-2)

Most work examining the effects of FDI has focused on developing countries that are lacking in technologically advanced capital and methods. Using data from Venezuela, Aitken and Harrison (1999) find that increases in foreign equity participation positively affects the productivity of Venezuelan firms while at the same time finding that this increase in foreign ownership has a negative effect on the productivity of wholly owned domestic firms in the same industry. Haddad and Harrison (1993), using data from Morocco, find some evidence of positive spillovers from technology while at the same time rejecting the hypothesis that the presence of foreign firms contributed to productivity growth. Borensztein et al. (1998) examine the effect of FDI on developing countries and find FDI to be more productive than domestic investment in the presence of a minimum level of human capital in the host country.

de Mello (1999), using data from the Summers and Heston data set (OECD and non-OECD countries), report mixed results, finding FDI's effect to be dependent on the degree of complementarity and substitution between FDI and domestic investment. Complementarity would suggest that foreign investment creates rather than destroys the opportunity to use existing technology in production.[6]

[6] De Mello argues that the Schumpeterian view of creative destruction is too simplistic to account for the possibility that under complementarity, FDI could enhance current technology rather than render it obsolete.

Until very recently, most work on FDI in the US has been mainly concerned with the location choices of foreign firms[7]. However, Figlio and Blonigen (2000) find that the introduction of a foreign firm in South Carolina increased wages seven times more in the community than a domestic one[8]. Additionally, the authors find that foreign employment leads to larger declines in per capita revenues and expenditures as well as a shift of expenditures away from education and toward transportation and public safety[9]. Branstetter (2000), like Jaffe (1996) and Jaffe et al. (1993), uses patent data to measure the impact of Japanese foreign direct investment in the transfer of knowledge to the United States and back to Japan. He finds that such activity does indeed facilitate technology and/or knowledge transfer between advanced countries.

Given that knowledge spillovers exist and seem to be local in nature, that these knowledge spillovers are present in the trading of goods and services across economies, and that FDI acts in the same manner as trade only magnified and accelerated, then FDI should increase productivity. However, evidence of FDI's impact is ambiguous at best. This suggests that there may be a missing piece in the analysis. While watching a demonstration may provide some minimal level of understanding of technology, for an understanding deep enough to use this existing technology in the generation of

[7]See Coughlin, Terza and Arromdee (1991), Woodward (1992) and Head, Ries and Swenson (1999).

[8]This result should not be surprising. The Law of Comparative Advantage states that a country will export the good(s) that is (are) relatively cheaper in autarky. It then follows that for a country to locate in another country it must be relatively more productive in the production of a good relative to the rest of the world. If workers are paid their marginal product, a boost in wages is assured.

[9]This result underscores the choice a government must make with limited tax resources and will be revisited a little later in the paper.

new technology, one needs some minimum level of education[10]. This idea dates back to Adam Smith and is articulated by Elmslie (1994) in the following passage:

> ...technology is not simply transferred in the superficial sense of its use in direct production. Foreign technology is incorporated ... through... learning to build these machines themselves. This presumes the existence of philosophers [engineers, scientists, and managers] whose business it is to dissect these machines in order to understand the technology that forms the connections that make up the machine. Once the machine is transferred, the workers themselves may make innovations to improve and simplify various parts and operations of the machine, but to transfer the technology as a whole requires that society has progressed to the point that it maintains philosophers. (pp. 659-660)

Using an endogenous growth framework and utilizing data for economies small enough to pickup the local nature of spillovers, this paper incorporates the idea that human capital augments FDI in the growth process.

1.4 A Simple Model of Endogenous Growth with FCDP Via A Scale Effect

Assume an economy that produces a single consumption good according to the following Cobb-Douglas production function:

$$Y_t = AH^{\alpha}K^{1-\alpha} \tag{1.1}$$

[10] As mentioned above, Borensztein et al. (1998) find that the effect of FDI on growth depends upon the host country having a minimum level of human capital. Benhabib and Spiegel (1994) find that human capital affects the speed of adoption of technology from abroad, an idea proposed earlier by Nelson and Phelps (1966).

where A is a positive constant traditionally thought of as augmenting the production process through technology, H is human capital and K is physical capital.

K consists of the total number of different intermediate goods. Each type of intermediate good is specific to no process in particular and is versatile enough to be used in conjunction with any other type of intermediate good. Capital accumulation takes place through the expansion of the total number of varieties of intermediate goods as specified by the following:

$$K = \left[\int_0^N x(j)^{1-\alpha} dj\right]^{\frac{1}{1-\alpha}} \tag{1.2}$$

where N is the total number of varieties of intermediate goods in the domestic economy.

In order to provide an incentive for undertaking the initial investment to create a new good, the inventor of each type of intermediate good j is granted an infinite monopoly over production of the good. The monopoly then sells the intermediate good of type j to producers at price $p(j)$. Demand for good $x(j)$ at price $p(j)$ will depend upon the marginal productivity of $x(j)$ in the production of final goods:

$$p(j) = A(1-\alpha)H^{\alpha}x(j)^{-\alpha} \tag{1.3}$$

It is assumed that the initial fixed cost required to invent and begin production, $F(N)$, is a function only of N-the total number of intermediate goods produced in the economy. This specification, commonly referred to as a scale effect, stems from the idea that the more types of goods that are produced in an economy the larger the knowledge base available to use in the production of new goods. Consequently, the inventor of the marginal good can use the existing economy-wide knowledge base to invent and set up production of the new good using what has already been discovered. The ability to use existing knowledge without cost lowers the cost associated with bringing the new good to market. This, and the assumption of a constant marginal cost of one to manufacture each unit thereafter allows profits of the monopolistic firm producing a good of type j at time t to be given by:

$$\Pi(j)_t = -F(N) + \int_0^\infty [p(j)x(j) - x(j)]e^{-rt}dt \tag{1.4}$$

where:

$$\frac{\delta F}{\delta(N)} < 0 \tag{1.5}$$

Maximization of (1.4) subject to(1.3) yields:

$$x(j) = HA^{\frac{1}{\alpha}}(1-\alpha)^{\frac{2}{\alpha}} \tag{1.6}$$

Substituting (1.6) into (1.3) reveals:

$$p(j) = \frac{1}{1-\alpha} \tag{1.7}$$

which is the markup over marginal cost.

Assuming zero profits in (1.4) and solving for the rate of return, r, yields:

$$r = A^{\frac{1}{\alpha}}\varphi F(N)^{-1}H \tag{1.8}$$

where

$$\varphi = \alpha(1-\alpha)^{\frac{2-\alpha}{\alpha}} \tag{1.9}$$

Individuals are assumed to have the often used constant intertemporal elasticity of substitution utility function:

$$U(c) = \int_0^\infty \frac{C^{1-\theta} - 1}{1 - \theta} e^{-\rho t} dt \tag{1.10}$$

Maximizing (1.10) over time and solving for $(\frac{\dot{C}}{C})$ yields the equation for the growth rate of consumption, γ_c:

$$\frac{\dot{C}}{C} = \gamma_c = (1/\theta)(r - \rho) \tag{1.11}$$

where ρ is the time preference of utility. This parameter measures the degree to which individuals value future utility less than current utility. θ is a measure of individuals' impatience. A higher value of θ is interpreted as a decrease in individuals' willingness to trade present consumption for future consumption. Equation (1.11) states that an increase in θ, which is interpreted as a decrease in the willingness to put off present consumption (and hence an increase in impatience), will require a larger difference between the interest rate (r) and the time preference of utility (ρ) to support a given γ_c.

Finally, substituting (1.8) into (1.11) yields the rate of growth of the economy:

$$\gamma = (1/\theta)[A^{\frac{1}{\alpha}} \varphi F(N)^{-1} H - \rho] \tag{1.12}$$

Equation (1.12) implies that the growth rate of the economy (γ) can be increased via a lowering of the cost of introducing new varieties into the production process. This lower cost increases the rate at which new intermediate goods are invented, thus speeding up growth.

For the purposes of examining the effect of FDI on growth, I decompose the variable of scale into intermediate goods which are produced by domestic firms (n) and those produced by foreign firms (n^*):

$$N = n + n^* \tag{1.13}$$

Dividing (1.13) by N results in:

$$\frac{N}{N} = \frac{n}{N} + \frac{n^*}{N} \tag{1.14}$$

which is simply the percentage of goods produced by domestic and foreign firms respectively.

Multiplying (1.14) by N results in:

$$N = N(\frac{n^*}{N} + \frac{n}{N}) \tag{1.15}$$

Rewriting (1.5) using (1.15) yields:

$$\frac{\delta F}{\delta(N)} = \frac{\delta F}{\delta(N(\frac{n^*}{N} + \frac{n}{N})} = \left(\frac{\delta F}{\delta(\frac{n^*}{N})} + \frac{\delta F}{\delta(\frac{n}{N})}\right) < 0 \tag{1.16}$$

While the scale effect presupposes that larger economies (as measured by the number of intermediate goods) will enjoy a lower cost to inventing new goods, specifying the scale effect (1.5) as (1.16) allows an inquiry into whether the introduction of a foreign good has a different effect on costs than the introduction of a domestic good. It is surmised that because each foreign firm has chosen to produce in the domestic economy, each must have *some* advantage (technology, production methods, information, or the like) that allows it to compete on foreign soil. Subsequently, as the percentage of products produced by foreign firms in the domestic economy ($\frac{n^*}{N}$) rises, so too does the overall stock of knowledge relative to the invention and/or production of the new goods[11]. This knowledge, being different from that being utilized domestically, decreases costs at a faster rate than if it were produced domestically.

Combining (1.16), a term to account for the convergence hypothesis–($\frac{N^*}{N}$), and (1.12) results in the final theoretical equation of growth[12][13]:

$$\gamma = (1/\theta)[A^{\frac{1}{\alpha}}\varphi F(\frac{n^*}{N}, \frac{n}{N}, N, \frac{N^*}{N})^{-1}H - \rho] \tag{1.17}$$

[11]A good example of such an increase in knowledge is the implementation of Japanese methods of just-in-time (JIT) and total quality control (TQC) during the 1980's.

[12]While Borensztein et al. (1998) empirically test for differential effects by including total flow investment over their relavent period, they do not address the distinction in their model. Furthermore, modeling the distinction via the variable scale (N) provides a way of testing for the presence of scale effects at the state level.

[13]Although the model is an "AK" variety that does not exhibit transitional dynamics (meaning $\gamma_K = \gamma_C = \gamma_Y$ at every instant in time), the open-economy dynamics which appear through the arguments in the cost function add another dimension to the analysis. Endogenous growth in this model is generated via the assumption that an increase in the number of varieties of intermediate goods does not contribute to diminishing returns. Each new good is neither a direct substitute or a direct complement in the production process. Subsequently invented intermediate goods contribute just as much to output as previously invented goods. The marginal product of the next not yet invented good is independent of the total stock of capital. A change in any of the parameters of the model leads to a one-time "jump" in the growth rates of capital, consumption and output per person. However, the short-term growth rates of these variables can and will differ from the growth rates that prevail in the long-run. The main interest for purposes of the ensuing empirical investigation concerns the argument (N^*/N). The assumption that the first and second derivatives of $F(\bullet)$ with respect to (N^*/N) are negative describes the movement of the economy from the short-run to the long-run growth rate. With no barriers to FDI and no trade, as $t \rightarrow \infty$ firms in each economy will fully exploit opportunities in each other's economy and so the number of intermediate goods produced in each economy will equalize and (N^*/N) will approach 1. The economy that was originally laggad in terms of the number of intermediate goods produced will grow faster than the leader. This is the convergence hypothesis. While the standard Solow model achieves this result via a different mechanism-diminishing marginal returns to capital-the results are the same.

$$\frac{\delta F}{\delta(N^*/N)}, \frac{\delta^2 F}{\delta(N^*/N)^2} < 0 \tag{1.18}$$

$(\frac{N^*}{N})$ is added to the cost function to account for the convergence hypothesis. An economy that produces fewer intermediate goods relative to a foreign economy (the total number of goods produced in the foreign economy is N^*) has an advantage in that in has a great deal to learn from the advanced economy. In other words, this economy has a greater potential for lowering its costs than does an economy that is more similar in terms of technological development[14]. This implies (1.18) where the costs are lower the larger the gap between N^* and N and as this gap shrinks, costs increase at a decreasing rate. The intuition behind the idea that there is a potential advantage to being relatively advanced resides in the process of knowledge formation and transfer. Assuming that an economy has sufficient capacity to learn from a more advanced economy, the further behind the economy is in terms of knowledge, the larger the potential gains from interaction. In terms of the time example, if a foreign country produced on domestic soil with advanced technology, all the years of toil and sweat creating the technology can be transferred just by watching and participating in the process. And the more that is unknown by the domestic residents, the more there is to learn. The more technologically backward the economy, the larger the potential gains. In comparison, two economies that are relatively equal in terms of

[14]The idea that there is an advantage to technological backwardness is usually associated with economic historians like Abromovitz (1986). The convergence hypothesis is also a result of the neoclassical production function that exhibits diminishing marginal returns to each input holding other inputs constant.

advancement can still gain from the interaction, yet the gains may not be immediate. They are more likely to come via close inspection of a foreign firm's process, detailed discussion with the firm's employees, and the interaction of ideas.

Recall that $\frac{n}{N}$ and $\frac{n^*}{N}$ sum to one (and thus their partial derivatives with respect to the cost function sum to the total effect of N). Given the dramatic circumstances surrounding the increase in FDI as described in the introduction, the relative contribution of each to growth in the United States environment will have far-reaching implications. It has already been surmised that a larger (N) presupposes a larger knowledge base, more inventors, and thus a faster expansion of knowledge and ultimately faster growth. However, the present specification allows a valuable inquiry into not only the growth process, but also the process whereby knowledge is generated and transferred across economies. Why would one suppose that the production of a foreign product might contribute relatively more to growth than a domestic product? Foreign firms bring with them different ways of producing, different information and different technology. Note that this bundle of intangibles does not necessarily have to be better. It just needs to be different, although the mere fact that a foreign firm has chosen to compete on foreign soil does suggest that the firm has or does something better than its domestic counterparts. Foreign firms bring a bundle of intangibles that domestic firms do not have. By watching and participating in a foreign firm's activity, domestic firms will not only learn from the foreign firms, but also ideas will emerge, thoughts provoked and growth sparked.

The empirical formulation motivated by equation (1.17):

$$\gamma = \xi_i + \eta_t + \beta_1 E_{it} + \beta_2 FDI_{it} + \beta_3 (FDI_{it} \times H_{it}) + \beta_4 H_{it} + \beta_5 Y(0)_{it} \qquad (1.19)$$

The above equation will be estimated using data from the 48 contiguous United States[15]. ξ_i is a vector of state fixed effects[16] and η_t represents the fixed effect of a particular time period. The initial level of GDP ($Y(0)$) is included to account for the conversion hypothesis[17]. E, which proxies for the scale variable in the cost function (N), is measured as total employment in a given state over each time period. Though not an exact measure of the total number of intermediate goods produced in an economy, a higher level of employment should correspond to a higher capital stock of intermediate goods used in production. As outlined in section 3.2, FDI is measured as the average share of non-bank employment in US affiliates of foreign firms in total state employment. In terms of the model, the measure proxies for

[15]As advocated by Barro and Sala-I-Martin (1999), a shock variable is added to the equation in the form:

$$S_{ij} = \sum_{j=1}^{9} \omega_{ij,t-T} [\frac{\ln(\frac{y_{jt}}{y_{j,t-T}})}{T}]$$

where $\omega_{ij,t-T}$ is the weight of sector j in state i's GDP at time $t-T$. The second term, $\frac{\ln(\frac{y_{jt}}{y_{j,t-T}})}{T}$, is the national average annual growth rate of GSP per worker in sector j over the same period. The nine sectors used are agriculture, mining, construction, manufacturing, trade, finance and real estate, transportation and utilities, services and government. The variable's purpose is to account for shocks that may affect states differently in order to bring stability to estimated coefficients across time periods. A low value of this variable would be typical of an economy specializing in sectors that happened to be slow growing over the time period in question.

[16]The state fixed effects would be replaced by regional fixed effects in the case of ordinary least squares and seemingly unrealted regression analyses.

[17]As pointed out by Pack (1994) there is no separate empirical equation for testing the presence of endogenous and exogenous growth. Thus, the endogenous growth models include $Y(0)$ in empirical equations to account for transitional dynamics which are assumed to be absent in the model. However, the open-economy dynamics that enter through the cost function in this model make the point moot.

the percentage of foreign intermediate goods used in the domestic economy. This is an improvement over previous studies which have used (investment) flows to proxy for this stock variable. More importantly, however, is that the *FDI* employment measures captures the true economic significance of foreign control in the domestic economy[18]. H is the stock of human capital in each state at the beginning of each period. $FDI \times H$ is an interaction term meant to capture the effect a well-educated workforce is likely to have on the absorptive capability of the flow of foreign assets (technology, knowledge, etc.). This also explains the earlier qualification that the potential gains to technological backwardness are conditional upon a sufficient capacity to learn from the technological leader.

1.5 Data and Econometric Issues

Data from the 48 continental United States is used to test the empirical equation. The growth literature is robust with the benefits of using such a data set. These benefits include the consistent manner in which data is collected across states and the similarity of states in terms of culture, language, legal framework, institutional characteristics and the like. In terms of the study of FDI, these benefits apply.

[18] As highlighted previously, our *FCDP* measure tracks extremely well with the percent of US GDP produced by foreign firms, albeit at a fraction of the output produced by foreign firms. This is part due to the employment measure's use of only non-bank employment whereas GDP includes output from banks and the financial sector. Another possibility is that foreign firms use more capital intensive processes which allow them to produce more output with less labor. Because the measure is used in the determination of rates of growth and not levels in output, this scaling issue is not a problem and needs no adjustment.

However, if spillovers tend to be more local than national in scope as Jaffe et al. (1993) suggest, then a state data set is more appropriate for capturing the growth effects of FDI.

Non-bank employment in the US affiliates of foreign firms comes from *Foreign Direct Investment in the United States: Operations of U.S. Affiliates of Foreign Countries*, which is collected by the Bureau of Economic Analysis and is available beginning in 1977.

Data for total state employment, Gross State Product (GSP), and the sectoral data used to calculate the shock variable also comes from the Bureau of Economic Analysis. All other data comes from the *Statistical Abstract of the United States* for the years 1978-1997.

Growth is measured as the average annual percentage change of Gross State Product (GSP)[19] per worker over the time-period and is calculated as $[\ln(y_i(T)/y_i(0)]/T]$[20]. Human capital is measured as the percent of the population with at least a college degree[21][22].

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[19]GSP is in chained 1996 dollars (1996=100).

[20]Where y is GSP per worker. GSP assigns product to the state in which it is produced whereas personal income is attributed to the state in which the owner of the input resides. Barro and Sala-I-Martin (1992) demonstrate how the results are empirically equivalent with either measure.

[21]A college degree is chosen as the basis for the variable due to an advanced US educational system (relative to the developing world) that has resulted in pushing most states toward the upper bound of the percentage of the population with a high school education. Not only does using a college degree provide more variation across states, but a college education seems more reasonable as a measure of the potential to take advantage of advanced technology. While a high school degree may be sufficient to allow a worker to run a machine, it seems reasonable that an advanced degree is needed to take advantage of technology as described in Elmslie (1994) above.

[22]Data for the human capital variable is not available for all years. Missing points were interpolated. It is generally accepted in the development literature that education changes very slowly over time. This fact will come into play in a discussion of the policy implications of FDI recruitment. New FDI provides instant results in the form of jobs and publicity, whereas changes in educational

Data is annual for the period 1978-1997; however, it is standard to construct panels in order to remove the effects of the business cycle. Multiple techniques will be employed in order to ensure that the findings are robust. 5-year panels, which are constructed for the years 1978-1982, 1983-1987, 1988-1992, and 1993-1997, use the methods of Least Squares Dummy Variable estimation (LSDV), Kiviet's (1995) method of correcting the Least Squares Dummy Variable technique for the possibility of endogeneity (LSDVc), and Seemingly Unrelated Regressions Analysis (SUR) with regional dummy variables[23]. For 10-year panels, constructed for the periods 1978-1987 and 1988-1997, SUR with regional dummy variables will be utilized. The full 20-year period of 1978-1997 is also estimated using Ordinary Least Squares with regional dummy variables.

The method of SUR estimates a separate equation for each time period (4 equations for the 5-year panel and 2 equations for the 10-year panel). By constraining the coefficients in each equation to be identical while allowing the intercept of each equation to vary—the intercept term for each equation is now interpreted as a time fixed effect—the SUR technique allows an alternative to OLS and the traditional panel data estimation method of LSDV. This method also allows variation of the estimation period to explore the stability of the coefficients over different horizons.

LSDV is OLS with time and state dummy variables. Islam (1995) advocates the

policy are less immediate and more difficult to quantify. See Schumacher (1973) for a discussion.

[23]For the period 1978-1982, the variables of growth, FDI and employment are averages over 1978-1982. $Y(0)$ is per worker GSP in 1978. The human capital variable is the percentage of the population with a college degree in 1978.

use of LSDV estimation in growth models. Such a specification is consistent with the concept of conditional convergence. Condition convergence is the hypothesis that poor countries tend to grow faster per capita than rich countries relative to their own steady-state. Absolute convergence, on the other hand, is the hypothesis that poor economies tend to grow faster per capita than rich economies with no regard to steady-state. Differences in steady-states can be due to numerous factors including differences in steady-state savings rates, differences in steady-state population growth rates and institutional factors. When testing for convergence across heterogeneous economies one typically uses a number of variables that attempt to proxy for differences in steady-state values. The inclusion of an economy specific intercept term eliminates the need for including what is commonly termed a "kitchen-sink" full of variables to account for differences in steady-state values when dealing with a set of heterogeneous economies. When testing for convergence across a group of homogeneous economies (like US states) it is assumed that differences in steady-state values are minimal. However, even though they are assumed to be relatively similar, homogeneous economies can be very different in reality. Allowing each state to have its own fixed effect is theoretically equivalent to allowing each economy to have its own steady-state value based upon unobservable differences.

LSDVc is a form of LSDV proposed by Kiviet (1995). Nickell (1981) was the first to point out the now well known result that dynamic panel data models with fixed effects suffer from biases and inconsistent estimators even if the size of the cross-sectional dimension is quite large. Anderson and Hsiao (1981) addressed this problem by estimating a consistent instrumental variable (IV) estimator via first differences with the first difference of the lagged right-hand-side variable ($Y(0)$ in this case) itself instrumented by its second lagged level. While the Anderson-Hsiao method produces consistent estimators for a large time dimension, most panel data models utilize a time dimension that is small. Kiviet (1995) directly estimates a small-sample correction (small in the time dimension) to LSDV estimation. Adam (1998) combines the small-sample bias estimation provided by Kiviet along with the Anderson-Hsiao method to a STATA routine that allows a direct application to data.[24]

1.6 Results

1.6.1 The Interaction Between FDI and Human Capital

Results for all regressions are reported in Table 1. The first four columns show results for the methods of LSDV, 20-year OLS, 5-year SUR, and 10-year SUR respectively. The last column, LSDVc is not directly comparable to the other methods and therefore discussion of these results will be held until the end.

As expected, all coefficients on $\ln(Y(0))$ are negative and significant at the 1% level. This finding is consistent with the conditional convergence hypothesis—the hypothesis that poor economies tend to grow faster than rich economies in per capita

[24] Islam (1995) uses an IV estimator based on Chamberlain (1982). Minimum Distance Estimation, as it is called, does not address the potential for small-sample bias.

terms relative to their own steady-state. Of note is the significant difference between the estimated coefficient using the LSDV method of estimation and the others. This finding is consistent with the work of Islam (1995), Sedgley and Elmslie (2000), and the discussion above. The inclusion of an economy specific intercept term strengthens support for convergence across economies.

Not surprisingly, ln(COLLEGE), our measure of human capital, is positive and significant at the 1% level across all estimation techniques. The importance of education in the growth process has been supported in paper after paper throughout the literature regardless of the economies and time-periods studied or the econometric techniques employed.

The most striking result is that the sign on the ln(FDI) coefficients are all negative and significant at the 1% level while the interaction terms (FDI*COLLEGE) are all positive and significant at the 1% level. These contradicting effects demonstrate that a minimum level of human capital is necessary for FDI to contribute more to growth domestic investment. Taking the derivative of each growth equation with respect to ln(FDI), setting them equal to zero, and solving for the level of human capital (COLLEGE) required to turn the total effect of FDI on growth positive, yields the college threshold which is reported for each regression at the bottom of Table 1[25]. Attention should be given to the stability of this threshold across the

[25] For example, using the results from the LSDV method of estimation yields: $\frac{\delta\gamma}{\delta \ln(FDI)} = .0516 + .0188 \ln(COLLEGE)$: $\ln(COLLEGE) = .0516/.0188 = \ln(2.74) = 15.56$. This is the percent of the population with a college degree required for a state to benefit more from FDI than domestic investment.

various econometric techniques employed. These techniques also allow the data to be separated and estimated over variety of period lengths—5-year, 10-year, and 20-year periods. Additionally, though not reported[26], the periods were shifted at one-year intervals both forward and back (for example, the 5-year techniques were re-tested using the periods 1977-1981, 1982-1986, 1987-1991, 1992-1996) to ensure stability. Changes to the estimated coefficients were minimal.

Figure 2 shows the implications of the results. The level of education for each state in 1978 is plotted on the y-axis and the average FDI over the period 1978-1997 is plotted on the x-axis. The two horizontal lines (at 15.56 and 12.04) depict the estimated range of the minimum educational thresholds needed for FDI to be more beneficial to growth than domestic investment. Notice that there are six states below the minimum estimated threshold (12.04) including Alabama, Kentucky, and Tennessee, all of which paid enormous sums to gain the business of major foreign firms over the period. There are twenty-three additional states between the minimum estimated threshold and the maximum estimated threshold (15.56). These include the states of North Carolina and South Carolina—two of the most aggressive states in the recruitment of foreign firms.

The inclusion of the scale variable, N, in the cost function in (1.12) and the resulting inclusion of E in (1.17) provides a natural test as to whether or not foreign firms and domestic have differential effects in the growth process. The pos-

[26]All unreported results are available upon request.

itive coefficient on ln(EMPLOYMENT) indicates that a larger level of employment (foreign or domestic) results in a higher growth rate[27]. The two terms, ln(FDI) and ln(FDI*COLLEGE) give the differential effect of foreign employment conditional upon a state's level of human capital. Thus the total effect of FDI on growth is shown by the coefficients on ln(FDI) and ln(FDI*COLLEGE) as well as ln(EMPLOYMENT). Note that the absence of statistically significant coefficients on ln(FDI) and ln(FDI * COLLEGE) would lead us to conclude that there is no difference between the growth effects of foreign and domestic firms.

Finally, attention must be given to the relative size of the coefficients on ln(EMPLOYMENT) and ln(COLLEGE). The LSDV coefficient on ln(EMPLOYMENT) is .0196 and the estimated coefficient on ln(COLLEGE) is .0999. The employment coefficients are interpreted as elasticities so a 1% change in employment will increase

[27]Those who are familiar with the growth literature will recognize the positive and significant coefficient on ln(EMPLOYMENT) as support for scale effects—the prediction that larger economies (in terms of population, employment, or firms) should grow faster than smaller economies. The idea has to do with the discussion in section 1.4. The invention of a new idea or good requires a one-time fixed cost. Once invented though, the use of the idea or the design of a good, can be used by anyone without having to re-invent the product or re-discover the idea. Further, each persons use of the idea in no way diminishes any other persons use of the idea. The larger a given economy, the more people that can use the idea or design and the faster the economy will grow. To this point the prediction of scale effects has not squared with the empirical evidence. As a casual example, consider that China and India (two countries with huge populations) should have an advantage relative to economies in the rest of the world. If the prediction of scale effects were correct, we should see these two economies growing faster per capita than any other economy in the world. Because endogenous growth models predict scale effects, much human capital has been expended on either trying to uncover scale effects empirically or trying to "fix" endogenous growth models to remove the scale effect. Support for the presence of scale effects in this paper was a great surprise—ln(EMPLOYMENT) is positive and significant in the LSDV results as well as in the 20-year OLS results. Because of its potential importance to the literature, research on this finding has already begun. Possible reasons for the support of scale effects in this paper would seem to be the result of controlling for FDI, the use of employment as a measure of scale, the focus on smaller economies (due to the local nature of spillovers), the use of the new econometric method which allows each economy to have its own steady-state, or some combination of the above. For more on scale effects see Jones (1995) and Jones (1999).

the growth rate around .02 percent per year. A 1% change in the percent of the population with a college degree will increase the growth rate of the economy by .09 percent per year. Thus assuming a state is at the educational threshold where foreign and domestic employment have the same differential effect, a very generous assumption given that 29 states in the sample are below it, education contributes almost five times more to productivity growth than does increased employment. Such a finding puts yet another exclamation point on the benefits of a well-educated workforce.

For Alabama in 1993, the year of the state's successful luring of Mercedes-Benz, a 1% increase in employment would require 21,741 new jobs while a .2% increase in the percent of the population with a college degree would require only 8385 more residents with a college degree. The 1993 Mercedes deal required Alabama to pay $253 million for 1,500 jobs or a 3.9% increase in employment. If the money had been spent on the education of 8385 residents, $31,172, which would cover the cost of four years of in-state tuition at the University of Alabama, would be available for each individual. This does not even consider the effects described in Figlio and Blonigen (2000) whereby money is likely to be shifted out of education to pay for the package.

1.6.2 Endogeneity and LSDVc Estimation

Potential endogeneity concerning LSDV is addressed through the use of LSDVc as described in the previous section. However, results using LSDV and LSDVc are not directly comparable. This is because LSDVc estimation requires first differences and lags. Using first differences and lags reduces the time dimension of the panel from T=4 to T=3 (n=192 to n=144). The important result here is that the estimated coefficients do not change substantially from LSDV to LSDVc even with a reduction in the time dimension. The result that the coefficient on $Y(0)$ becomes more negative (and strengthens support for the convergence hypothesis) is in accord with Islam's (1995) result using the technique of Minimum Distance Estimation. The coefficients on ln(COLLEGE), ln(FDI*COLLEGE), and ln(EMPLOYMENT) retain significance at the 1% level. ln(FDI) is still significant at the 10% level, while the estimated threshold remains within the bounds of the other techniques (12.83). Further, if one compares LSDV (not reported) and LSDVc estimates for both using T=3, the largest coefficients change is around 3% (for ln(FDI)).

Two additional unreported regressions deserve mention. First, LSDVc was performed using T=4 with the one-year lags. Again, coefficient changes were minimal. Finally, though it was only used as an input into the LSDVc method for T=3, the first-stage Anderson-Hsiao IV method (estimation in first-differences with the lag of Y(0) as an instrument) is in itself a recommended estimation technique under the circumstances[28]. The method produced estimated coefficients that did not differ substantially in terms of signs or significance[29].

[28]See page 152 of Baltagi (2001) for a demonstration.

[29]In the interest of completeness, regressions were also performed using the initial values of all right-hand side variables (as opposed to period averages). No significant changes occurred.

1.7 Conclusion

Because of the difficulty inherent in competing on foreign soil, firms that locate in a foreign market are assumed to have superior technology and/or knowledge. If, as suggested by the trade literature, growth effects are present in the trading of goods and services across countries, one would expect at least as strong an effect from the production of the goods in the domestic country. However, results from previous studies have been unconvincing.

Using data from the 48 continuous United States from 1978-1997, this paper demonstrates that foreign direct investment, as measured by foreign control of the US economy in non-bank employment, is more productive than domestic investment in the presence of a minimum level of human capital.

Figlio and Blonigen (2000) argue that because over 75% of expenditures by state development agencies are aimed at foreign investment, states and communities may be willing to pay a greater price to attract foreign firms. Given the results of this paper, only the states positioned solidly above the threshold should even consider paying more to attract a foreign firm relative to a domestic firm.

Further, foreign (and domestic) firm recruitment is about jobs and publicity. When public officials lure a high profile firms firm to their state, they gain in the eyes of the voting public. Voters perceive that their elected officials are actively seeking to make their plight better and the officials gain re-election. However, the relative size of the estimated coefficients on ln(EMPLOYMENT) and ln(COLLEGE) suggest that education should be priority number one.

The problem is that education policy requires time to take effect and when it does the impact is not obvious. Firm recruitment brings the immediate benefit of high-paying jobs and in the case of foreign recruitment in the presence of below-threshold human capital attainment, the costs are not immediately, if ever, discovered.

Such a "quick-fix" mentality can cause an economy to tend towards what the development literature calls a low-level equilibrium. Because a state has a low level of human capital, it may have to increase the incentives it offers if it wants to lure a foreign firm (to make up for a lack of productive workers). When the state shifts money from education to pay for the package, education suffers. The next time the state courts a potential foreign firm, its educational attainment has lost ground on other states and so once again it must pay more for the firm's business. This sentiment is echoed by Bo Torbert, a former chief justice of the Alabama Supreme Court who sued the state over school quality:[30]

> If we had spent more money in the last 20 years on education, we would have a better-trained work force. Maybe we wouldn't have to give as much in incentives to get Mercedes here.

[30]From Allen Myerson's article, "O Governor, Won't You Buy Me A Mercedes Plant?", in *The New York Times*, September 1, 1996, Section 3, page 1, column 2.

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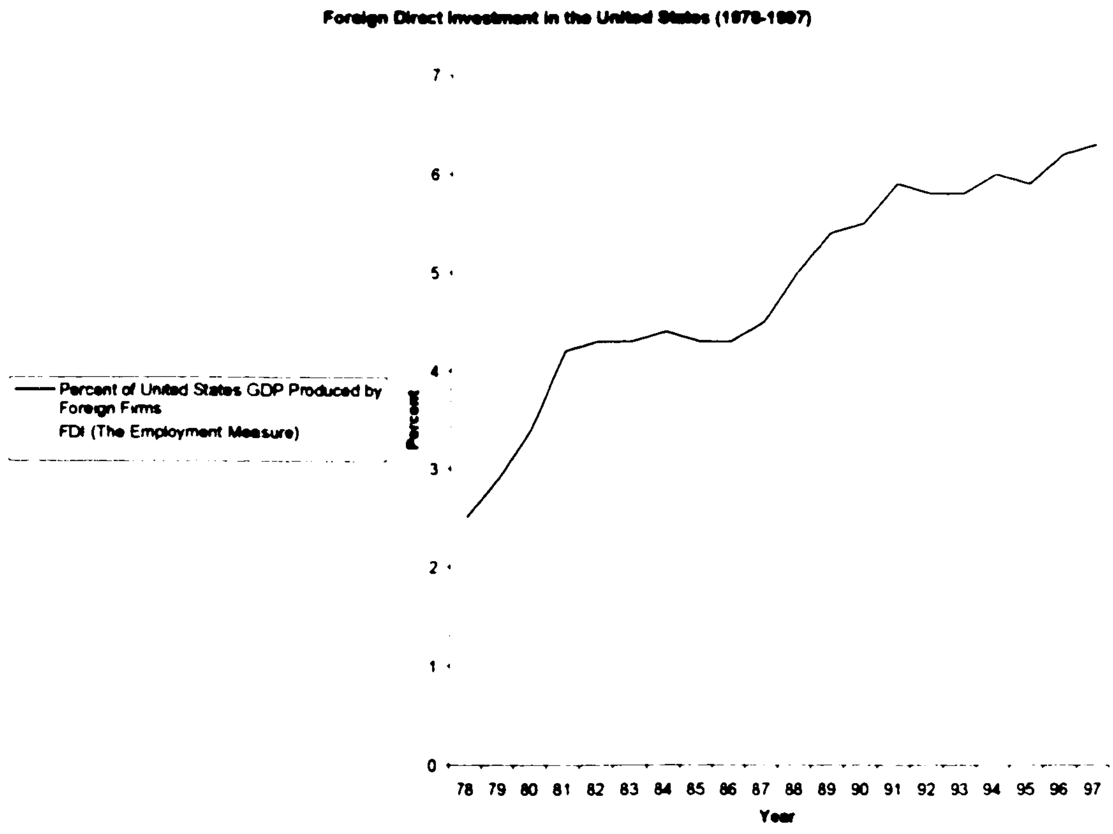

Figure 1.1: Foreign Direct Investment in the United States (1978-1997)

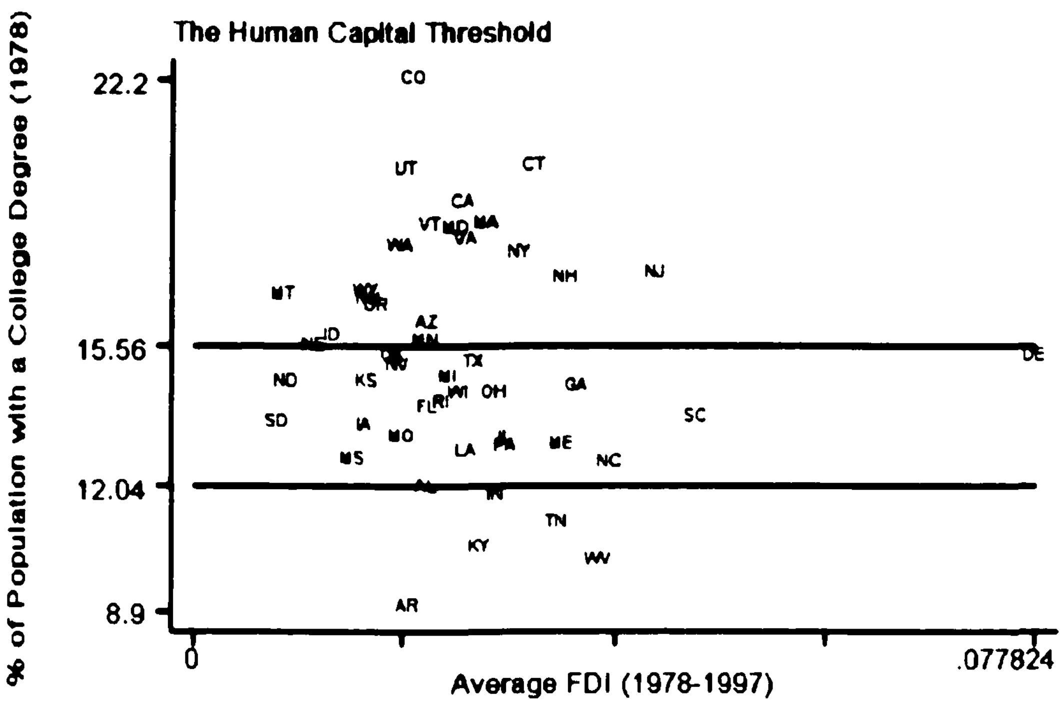

Figure 1.2: The Human Capital Threshold and US states

	METHOD				
	LSDV	20-year OLS	5-year SUR	10-year SUR	LSDVc
Independent Variable					
ln (Y(0))	-0.0880 ***	-0.2170 ***	-0.0283 ***	-0.0286 ***	-0.1361 ***
	(0.0129)	(0.0030)	(0.0040)	(0.0044)	(0.0157)
ln(COLLEGE)	0.0999 ***	0.1428 ***	0.0865 ***	0.0914 ***	0.1007 ***
	(0.0258)	(0.0313)	(0.0184)	(0.0238)	(0.0352)
ln(FDI)	-0.0516 ***	-0.0927 ***	-0.0526 ***	-0.0560 ***	-0.0490 *
	(0.0177)	(0.0224)	(0.0132)	(0.0174)	(0.0265)
ln(FDI*COLLEGE)	0.0188 ***	0.0372 ***	0.0201 ***	0.0225 ***	0.0192 **
	(0.0065)	(0.0084)	(0.0047)	(0.0063)	(0.0093)
SHOCK	0.6168 ***	-0.0758	-0.7611	2.2689 ***	0.7127 ***
	(0.1193)	(0.8066)	(0.7038)	(0.9947)	(0.2220)
ln(EMPLOYMENT)	0.0196 ***	0.0007 **	0.0007	0.0006	0.0377 ***
	(0.0072)	(0.0003)	(0.0004)	(0.0005)	(0.0095)
R^2	0.564	0.7577			0.5771
College Threshold	15.56	12.08	13.69	12.04	12.83

* significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level

NOTES:

1. State specifice variables, regional variables, time variable and constant terms are not reported but available upon request.
2. In the case of 5-year SUR, the system contains 4 equations (one for each 5 year period). All coefficients except for the constant term are constrained to be the same for all periods.
3. In the case of 10-year SUR, the system contains 2 equations (one for each 10 year period). All coefficients except for the constant term are constrained to be the same for all periods.
4. LSDV and LSDVc are not directly comparable. Because LSDVc requires the lag and first difference of variables, the number of observations in this regression is reduced to 144. See text for discussion.
5. Robust standard errors are reported for the 20-year OLD, LSDV and LSDVc regressions.

Table 1.1: FDI and per capita GDP growth (1978-1997)

Chapter 2

Considering the Source: Does Foreign Direct Investment's Country of Origin Matter to Economic Growth? Evidence from the US States

2.1 Introduction

In the first essay of this dissertation it was demonstrated that FDI in the United States increases a state's per worker growth rate of output more than domestic investment when coupled with a minimum level of human capital. While this result is not entirely new, one area that has yet to be addressed in the literature is whether FDI from different sources affects growth differently.[1]

While the benefits of foreign firms to the US include increased employment, increases in industry and technological know-how, management skills, and information, the potential costs are less straightforward. Concerns have been raised about the quality of the jobs created by foreign firms in the US. Critics of FDI in the US argue that foreign firms may transfer lower skilled, lower paying, parts of production abroad and retain higher skilled, higher paying jobs at home. Further, there may be multiplicative effects through the domestic economy as foreign firms are more likely to obtain inputs from the source country rather than domestically. Such activity allows foreign firms to gain free access to US markets (circumventing tariffs and quotas) while retaining the best jobs at home.

Graham and Krugman (1993) best frame the essential problem:

> ...the longer term question is whether and how foreign-owned firms will behave differently from domestic ones. The fear once expressed in Europe about US firms and now expressed in the United States by Japanese and (to some extent) European firms is that these firms will use their

[1] The result was previously demonstrated by Borensztein, DeGregorio, and Lee (1998), and Xu (2000) for developing countries. It is, however, new for advanced countries.

> operational control to the detriment of the host country. Accusations by critics ... are that foreign-owned firms in the US will shift high-wage jobs and high value-added production to the parent country and shift sophisticated activities such as R&D abroad. The results will, so these critics assert, be to reduce that growth rate of the host economy... Such concerns are not absurd in the light of theoretical analysis. Multinational firms are created for a reason; they are more than the sum of their parts, and their subsidiaries therefore ought to behave differently from purely domestic firms. It is not implausible that this difference in behavior might include hiving off some high-level activities to the parent firm. On the other hand it is not certain either: the conceptual foundations of discussion about FDI are fuzzy enough to allow many hypothesis. (p. 31)

Graham and Krugman (1991) use value added, compensation, and R&D per worker to demonstrate that foreign firms, regardless of the source country, "look" similar to US firms. However, they do admit that "in the public mind, however, there is an important distinction among firms of different nationalities. Many US citizens and policymakers may be willing to accept the idea that British, Dutch, and Canadian firms act much like American firms, and indeed in many cases may for all practical purposes be American firms. Many concerns about inward FDI, however, are focused on Japanese firms." (p. 74) Such concerns seemed to coincide with the rise in the role of Japanese firms in the US economy in the 80's and 90's where Japan went from last to second among the major sources.

The results of this essay are twofold. First, focusing on the top seven source countries—France, UK, Japan, Germany, Netherlands, Canada, and Switzerland—I will determine which countries' firms differ, from domestic firms and each other, in terms of their effect on the output per worker of the states in which they locate.

Second, I will attempt to uncover what it is about the source country and/or its firms that contribute to the differing effect.

Though this paper supports the public's popular belief that different sources have differing effects on growth, the differences themselves are shown to be quite the opposite of public perception. Japan, it turns out, contributes significantly more to growth than the so called "American-like-firms". The primary contribution of this essay, however, is the discovery of the pattern of the differences. For sometime economists, especially economic historians, have surmised that growth, via technology transfer, is dependent upon how closely related are the source countries' and host country's endowments. Findlay (1978a) presents micro-foundations of a firm's decision to adopt and adapt foreign technology based upon differences in domestic factor prices. Using the multinational corporation as the major force of contagion, I model the cost of technology transfer as an increasing function of the difference between the source economies' and host economy's endowments as measured by capital-labor ratios and introduce this cost into an endogenous model of economic growth. I then provide the first empirical support that growth, via technology transfer, is dependent upon how closely related are the source countries' and host economy's endowments. Results cement the multinational firm as the main engine of contagion. *However, most importantly, results imply that on average no state benefited more from its particular mix of FDI than domestic investment, as measured by growth in per worker output, over the period from 1978-1997!* The implications of this essay should be quite helpful to the recruitment of foreign firms by both the advanced and underdeveloped economies of the world.

2.2 What is foreign direct investment and how is it measured?

The US Department of Commerce considers an investment as direct when any foreign entity (whether a person, firm, partnership, government, or etc.) owns or controls at least 10 percent of a US firm[2]. This 10 percent threshold is considered evidence that the foreign entity has "a lasting interest in or a degree of influence over management". (Quijano, 1990, p.29) While 10 percent may not seem sufficient to guarantee a foreign entity's long-term commitment to or sway in the operations of the US firm, Graham and Krugman (1991) cite that on average a foreign entity controls 78.8 percent of the domestic firm's equity. Such a large majority makes the 10 percent threshold irrelevant. Further, the authors' claim that the Bureau of Economic Analysis, the agency responsible for collecting data on foreign direct investment in the US, has found little change even after raising this threshold to as high as 50 percent.

To this point, the literature has expressed FDI as a flow measured in some currency (usually expressed as a percentage of domestic GDP). Although it is natural to think of FDI as a flow, such a measure makes it difficult to determine the total

[2]At this point the US firm is considered a US affiliate of the foreign firm controlling it.

impact of FDI. Foreign parents transfer a wealth of assets not capable of being priced and not constricted to the time period in which the initial investment takes place. These may include, but are not limited to, industry and technological know-how, management skills, information, and the like. A one-time investment by a foreign firm tells nothing about the subsequent flow of benefits that are likely to occur as the foreign firm participates in operations of the domestic firm. Further, the flow of benefits may or may not be reflected in the value of the investment. Consequently, a stock measure is best suited to capturing the immeasurable and infinitely lived flow of these intangibles[3].

Of the data available for constructing a stock measure of FDI for the US economy, Graham and Krugman (1991) favor using non-bank employment in US affiliates of foreign firms--the employment measure. This is due to the possibility of measurement error that is associated with the other common measures. The most common measure, the balance of payments-based measure of the cumulative stock of FDI in the US, is calculated at book value and most likely understates current market values of foreign owners' equity. The other common measure is total assets under control of foreign owned firms. The asset measure, as it is called, is dominated by the assets of financial firms that have no bearing on production.

Using non-bank employment in the US affiliates of foreign firms, a stock ratio is formed by expressing the employment measure as a percentage of total employment

[3]The use of flow measures is most likely not due to choice but to data availability. For example, Borensztein et al. (1998) express their inability to construct a stock measure from the flow data available to them. Such a measure, they admit, would better fit their theoretical model.

in the economy. This ratio will then be a measure of foreign control of the domestic economy. This stock variable will proxy for the flow of benefits at any point in time.

Non-bank employment is used mainly because foreign banks do not seem to act in a similar way as other foreign firms. According to Graham and Krugman (1991) foreign banks in the US are dominated by the presence of Japanese firms. And though there are many theories as to the reason for this disproportionate presence, foreign banks are not well behaved in terms of the theory of industrial organization. As such, their inclusion is likely to bias results.

2.3 The Empirical Equation

This essay extends the analysis of the previous essay from a two-country to a multi-country world. The only point of departure is the decomposition of FDI_{it}(FDI in state i at time t) into FDI from each of the seven major source countries such that:

$$FDI_{it} = \sum_{c=1}^{7} FDI_{itc} = FDI_{itFrance} + FDI_{itEngland} + FDI_{itJapan} + FDI_{itGermany} + FDI_{itNetherlands} + FDI_{itSwitserland} + FDI_{itCanada} \quad (2.1)$$

which results in the following empirical equation:

$$\gamma = \xi_i + \eta_t + \beta_1 E_{it} + \delta_c FDI_{itc} + \varphi_c(FDI_{itc} \times H_{it}) + \beta_4 H_{it} + \beta_5 Y(0)_{it} \quad (2.2)$$

The above equation will be estimated using data from the 48 contiguous United States[4]. ξ_i is a vector of state fixed effects[5] and η_t represents the fixed effect of a particular time period. The initial level of GDP ($Y(0)$) is included to account for the conversion hypothesis[6]. E, which proxies for the scale variable in the cost function (N), is measured as total employment in a given state over each time period. Though not an exact measure of the total number of intermediate goods produced in an economy, a higher level of employment should correspond to a higher capital stock of intermediate goods used in production. As outlined in section 3.2, FDI is measured as the average share of non-bank employment in US affiliates of foreign firms in total state employment. In terms of the model, the measure proxies for the percentage of foreign intermediate goods used in the domestic economy. This is an improvement over previous studies which have used (investment) flows to proxy for this stock variable. More importantly, however, is that the FDI employment measures captures

[4] As advocated by ?, a shock variable is added to the equation in the form:

$$S_{ij} = \sum_{j=1}^{9} \omega_{ij,t-T}\left[\frac{\ln\left(\frac{y_{jt}}{y_{j,t-T}}\right)}{T}\right]$$

where $\omega_{ij,t-T}$ is the weight of sector j in state i's GDP at time $t-T$. The second term, $\frac{\ln\left(\frac{y_{jt}}{y_{j,t-T}}\right)}{T}$, is the national average annual growth rate of GSP per worker in sector j over the same period. The nine sectors used are agriculture, mining, construction, manufacturing, trade, finance and real estate, transportation and utilities, services and government. The variable's purpose is to account for shocks that may affect states differently in order to bring stability to estimated coefficients across time periods. A low value of this variable would be typical of an economy specializing in sectors that happened to be slow growing over the time period in question.

[5] The state fixed effects would be replaced by regional fixed effects in the case of ordinary least squares and seemingly unrealted regression analyses.

[6] As pointed out by ? there is no separate empirical equation for testing the presence of endogenous and exogenous growth. Thus, the endogenous growth models include $Y(0)$ in empirical equations to account for transitional dynamics which are assumed to be absent in the model. However, the open-economy dynamics that enter through the cost function in this model make the point moot.

the true economic significance of foreign control in the domestic economy[7]. H is the stock of human capital in each state at the beginning of each period. $FDI \times H$ is an interaction term meant to capture the effect a well-educated workforce is likely to have on the absorptive capability of the flow of foreign assets (technology, knowledge, etc.). This also explains the earlier qualification that the potential gains to technological backwardness are conditional upon a sufficient capacity to learn from the technological leader. The terms δ_c and φ_c are now a vector of coefficients on each source countries FDI and the accompanying interaction term respectively.

2.4 Data and Problems Due to the Collection Process

Data from the 48 continental United States is used to test the empirical equation. The growth literature is robust with the benefits of using such a data set. These benefits include the consistent manner in which data is collected across states and the similarity of states in terms of culture, language, legal framework, institutional characteristics and the like. In terms of the study of FDI, these benefits apply. However, if spillovers tend to more local than national in scope as Jaffe et al. (1993) suggests, then a state data set is more appropriate for capturing the growth effects

[7]As highlighted previously, our *FCDP* measure tracks extremely well with the percent of US GDP produced by foreign firms, albeit at a fraction of the output produced by foreign firms. This is part due to the employment measure's use of only non-bank employment whereas GDP includes output from banks and the financial sector. Another possibility is that foreign firms use more capital intensive processes which allow them to produce more output with less labor. Because the measure is used in the determination of rates of growth and not levels in output, this scaling issue is not a problem and needs no adjustment.

of FDI.

Non-bank employment in the US affiliates of foreign firms comes from *Foreign Direct Investment in the United States: Operations of U.S. Affiliates of Foreign Countries*, which is collected by the Bureau of Economic Analysis and is available beginning in 1977[8]. This essay follows the previous one in that it uses a stock measure of FDI for the US economy using non-bank employment in US affiliates of foreign firms-- the employment measure. Using non-bank employment in the US affiliates of foreign firms, a stock ratio is then formed by expressing the employment measure for each source country as a percentage of total employment in the economy. The stock ratio will then be a measure of each source countries foreign control of the domestic economy. One problem that does exist is that due to confidentiality requirements the BEA does not report data for which there exists only one firm from a particular source country in a state in a in a given year. For example, if there exists only one Japanese firm in the state of Wyoming in 1977, data on the other six source countries will be available (assuming there is more than one firm from each country) yet FDI data concerning the presence of Japan in Wyoming for 1977 will be censured. The number of complete observations lost a result of this policy is amounts to less than 10% of the total. However, methods designed to reconstruct the missing data are discussed in the next section.

Data for total state employment, Gross State Product (GSP), and the sectoral

[8]Available on-line at www.bea.gov.

data used to calculate the shock variable also comes from the Bureau of Economic Analysis. All other data comes from the *Statistical Abstract of the United States* for the years 1977-1997.

Growth is measured as the average annual percentage change of Gross State Product (GSP) per worker and is calculated as $\ln(y_i(T)/y_i(0))/T$[9]. Human capital is measured as the percent of population with at least a college degree.

Data is annual for the period 1977-1997, however in order to maximize the number of observations to best deal with the added independent variables needed to estimate each source countries' FDI effect 3-year panels have been constructed[10]. Though 3-year panels are not as prevalent in the growth literature as the 5-year panels which were utilized in the previous essay, they are commonly used. The reason for the use of panels in growth econometrics is to eliminate the effects of the business cycle in estimation. (Growth, after all, is not concerned with the short-term fluctuations.) While 5-year panels are generally thought sufficient to remove these effects, there is not a hard and fast rule concerning panel length. The inclusion of time fixed effects and the shock variable should suffice to eliminate any residual business cycle effects[11]. The 3-year panels are constructed for the years 1977-1979, 1980-1982, 1983-

[9]GSP assigns product to the state in which it is produced whereas personal income is attributed to the state in which the owner of the input resides. Barro and Sala-i-Martin (1992) show that, empirically, results are similar

[10]Data for the human capital variable (percent of state population with at least a college degree) is not available for all years. Missing points were interpolated. It is generally accepted that education changes very slowly over time. See Schumacher (1969) for a discussion.

[11]In fact the same regression was estimated using 5-year panels. The only differences were a slight loss of significance in some of the joint country levels. Besides increasing the number of observations, 3-year panels allowed more accurate estimation by placing less weight on any one missing X-variable.

1985, 1986-1988, 1989-1991, 1992-1994 and 1995-1997 and will be estimated using the method of Least Squares Dummy Variable estimation (LSDV), which is Ordinary Least Squares estimation (OLS) with time and state dummy variables[12].

2.5 Missing X-variable Discussion

While the econometric literature is robust with methods for dealing with missing dependent variables (Y), techniques that address the problems associated with missing independent variables (X) are less common. The standard practice is to eliminate observations without a complete set of X variables which results in what is termed an unbalanced panel—a panel such that not every i individual unit has the same number of t observations[13]. The remaining observations are then analyzed using panel data estimation techniques. This is the technique that is recommended and discussed by Baltagi (2001). Though this results in unbiased and efficient estimators as long there is no correlation between the missing variables and the dependent variable, such a practice can be a problem if too few observations remain[14]. There is also the question of whether or not such a technique fails to take advantage of all information contained in a data set.

[12]Islam (1995) advocates the use of LSDV estimation in growth models. Such a specification is consistent with the concept of conditional convergence and is equivalent to allowing each economy to have its own steady-state value based upon unobservable differences. Sedgley and Elmslie (2000) extend this analysis to US states.

[13]A balanced panel could be retained if the variable(s) with missing observations are simply eliminated from the model. The method is termed complete case analysis.

[14]The classic example concerning correlation between the missing variables and the dependent variable occurs in survey data when high-income people fail to answer income related questions.

This paper will utilize an unbalanced panel as well as two methods for replacing the missing variables and thus allowing all observations in the data set to be utilized. Both of these methods make use of what is termed a missing data mechanism (Rubin 1976). With $Y = Y_1 ... Y_n$ observations and $X = X_1 \ldots X_k$ dependent variables, a missing data mechanism is simply a $n \times k$ matrix with each element of the matrix equal to 1 if the X for that observation is included in the data set and 0 if it is missing. This missing data mechanism is simply included into the regression after the missing observations are filled to account for any effects resulting from the filled in data.

The simplest method for filling in missing data is to simply replace missing observations with the mean of the X variable. Unconditional mean imputation, as it is called, results in inconsistent and biased estimates and thus is not recommended (Little 1992)[15]. An alternative method, called conditional mean imputation, is to use the information contained in the observed X's in the data set to impute the missing X's. In the first method the entire data set used to construct the panels for this essay (i.e. the full 21 years from 1977-1997) is used to impute missing values which may occur at the panel intervals. To avoid subjectivity, missing X's were replaced with the closest available backward observation. In the case of missing X's in the initial year of the data set (1977) the closest forward observation was used. In the second method,

[15] Little (1992) does not consider unconditional mean imputation in panel data. With panel data the missing observations would be replaced not by the mean of the entire X variable but with the mean of that particular i unit. While the properties of such a method have not been addressed, the panel data version of this method must be an improvement over the simple OLS version and is more closely related to conditional mean imputation than the unconditional version.

after eliminating all observations with a missing X,each X variable that contained a missing X was regressed on the remaining X variables. The estimated coefficients are then used to predict values for the missing observations and fill the set. A more detailed discussion of these techniques can be found in Little (1992).

2.6 Results

2.6.1 Missing Data Results

Results from the three methods described in the previous section are presented in Table 1.

The coefficients on ln(Y0) are significant at the 1% for each of the three methods. The negative coefficient on ln(Y0) is consistent with the convergence hypothesis and supported in the literature. The coefficients on ln(COLLEGE) are positive and significant at the 1% level for the imputed and predicted methods and at the 10% level for the unbalanced panel. Education has consistently been a positive and significant variable in growth equations[16]. The variable of scale ln(EMPLOYEMNT) is significant at the 10% level for the unbalanced panel (and also at the 15% level for each of the other two methods though not reported). As explained in the previous essay this essay is testing the hypothesis that larger economies grow faster than smaller

[16]The SHOCK variable, though positive and significant at the 1% level for all methods, has no important economic interpretation in this context. Its purpose is to bring stability to the estimated coefficients as described in an earlier footnote. Its significance, however, is provides some assurance that the business cycle effects are being accounted for in the regression.

economies.

The remaining coefficients measure the growth effects of FDI from specific sources. The columns to the right of the estimated coefficients for each method (labeled Threshold) is the minimum (or in some cases maximum) educational threshold which makes FDI from the source country more (or less) productive than domestic investment[17]. As in the case of Switzerland, FDI from some sources is more productive than domestic investment at low levels of human capital yet becomes less productive at higher levels of human capital. The reported threshold in these cases is the level of human capital at which the country specific growth effect turns negative. Note that with a few exceptions the different methods produce thresholds that are reasonably similar with the only sign change occurring for France. Though the thresholds appear to be wildly different across methods (69.25, 1.06, and 6.26) upon closer scrutiny one should realize that the 62.25 is the human capital threshold that turns the country specific effect positive while the other two thresholds turn the country specific effect negative[18]. At no time during the sample period (1977-1997) did a state's human

[17] Using the estimated coefficients for the For instance, Switzerland's total FDI effect on growth is:

$$\gamma = .02356 \times \ln(SWITZERLAND) - .0089 \times \ln(SWITZERLAND) \times \ln(COLLEGE)$$

and:

$$\delta\gamma/\delta\ln(SWITZERLAND) = .02356 - .0089 \times \ln(COLLEGE)$$

Setting the above derivative equal to zero and solving for COLLEGE gives 11.09 which is the Threshold. Note that the initial effect of FDI from Switzerland is greater than the domestic effect, yet the total effect decreases at higher levels of human capital.

[18] Remember from the previous essay that the total contribution of FDI consists of not just the two country specific terms but also the ln(EMPLOYMENT) term which measures the increased productivity of any job.

capital endowment reach above 62.5 or below 6.26 (the high and low in the sample is 31.7 and 8.62 respectively). Thus the estimates across methods are consistent in that France's country specific effect is always negative.

The results of joint significance tests on the two coefficients for each country are reported at the bottom of table 1. These tests, along with the pattern of the thresholds by country will be discussed at a later point in the essay.

2.6.2 Testing for Differential Effects

As mentioned in the introduction to this essay, a major question concerning the debate in regards to FDI in the US has centered on whether or not foreign firms behave differently from US firms and from one another. The important question however is not whether they behave differently but whether they in fact have different effects. In fact, the employment measure of FDI is perfectly suited to directly test the differential growth effects of the jobs that are exported by foreign multinationals.

First off, FDI is measured as the percentage of each state's employment that results from a particular source country. The interaction term is simply this percentage multiplied by the states human capital. Because ln(EMPLOYMENT) is measuring the total effect of all employment on growth, each two country set is individually testing whether or not their exists a differential effect for each source. As a result, if a particular two country set is jointly significantly greater than zero, there exists a difference between the effect of the source country's employment and domestic employment[19]. These tests are reported at the bottom of Table 1.

The tests support Japan (significant at the 1% level across all methods) and Switzerland (significant at the 1% level in two methods and at the 10% level in the other) as having the most distinct country specific effects. (They are also at opposite extremes with Japan distinctly positive and Switzerland distinctly negative. This is a point that will be revisited in the next section.) Germany and the UK are significant in two of three methods. Tests fail to reject the hypothesis that FDI from France, the Netherlands, and Canada is significantly different from domestic investment.

A final question to consider is whether the country specific effects differ from one another under realistic conditions. That is, taking into account the interaction between FDI and human capital, do the country specific effects differ from one another? This is done by testing the country specific effects, evaluated at the average level of human capital in the sample (18.25), against one another. Results of these tests from each of the three methods are reported in Table 2. The tests support the hypothesis that significant differences exist in the effects of FDI across sources.

[19]There is a small problem with this analysis. Total employment in a state consists of domestic employment plus the sum of all foreign employment. If the seven source countries examined in this essay totaled to the entire stock of foreign employment then the only excluded employment category would be that of domestic firms. In such a case the analysis above would be correct. However, there is a small portion of foreign employment unaccounted for by the seven major sources. This "other foreign employment" category has been excluded from the regression. Because this is not an official BEA category it was calculated by subtracting the sum of the seven major sources from total foreign employment. Partly due to the methods used to fill missing X variables and partly due to BEA measurement methods, this constructed "other" category was often negative. It is for this reason that the variable was determined to be unreliable and thus excluded. In earlier non-logarithmic regressions, however, negative values were constrained to be zero and the total "other" effect was found to be not significantly different from the excluded domestic percentage. It is for this reason that it can be justified
that the analysis above is valid.

2.7 Technology Transfer: Is something missing?

Although the previous section demonstrates that significant differences exist between the effects of FDI and domestic investment as well as between FDI from different source countries, closer examination is needed to uncover the pattern of these differences. Because the literature points to growth through FDI as a "conduit for transferring advanced technology" (Lim 2001) it is in the area of technology transfer that I focus the analysis.

Most economists are by now in agreement with Findlay's (1978a) statement that "the creation and diffusion of new technology is undoubtedly the major determinate of economic growth." (p. 1) Despite this agreement debates concerning the nature of this technology and its mechanism of transfer remain unsettled. If technology is a pure public good that is magically floating around in space for the taking, as it is in the neoclassical models of Solow (1956) and Swan (1956), then in the long run, growth rates of output in all economies should be equal to one another at the rate of worldwide technological progress. Empirical support for this hypothesis, except when limiting the sample to developed countries, has not been found.

The endogenous growth theory grew out of this dissatisfaction in which economic growth was determined by factors outside the model. As the name implies, growth in this group of models was the result of technology and/or knowledge spillovers that were the result of either unintentional (Romer, 1986) or intentional (Romer 1987, 1990 and Aghion and Howitt 1992) decisions by individual firms. Although these models are an improvement over the neoclassical models described above, one must assume that technology is national rather than international in scope in order for their implications to match an empirical record that provides evidence of persistent and growing differences between the rich and poor countries of the world[20].

Jaffe, Trajtenberg, and Henderson (1993) show through the use of patent data that knowledge spillovers tend to occur not only at the country level but more specifically at the state and SMSA level and spread slowly over time. However, it is hard to conceive that in a world that is becoming more integrated everyday that mechanisms are not in place to help in the spread of this knowledge. The mechanisms to which I am referring are international trade of goods, services, and factors and the multinational corporation. Findlay implies that "contagion" mechanisms have been in place for the better part of modern history and describes the modern evolution:

> While the migration of individuals, such as Dutch shipwrights to Sweden or Italian architects to Russia, was the chief form of technological diffusion by "contagion" in earlier times, their role is now taken over by large organizations such as the multinational corporations. This development runs parallel to the replacement of the picture of the solitary inventor or innovator himself, as painted so lovingly by Schumpeter for instance, by that of the routinization of this process in the work of large teams in the R&D departments of these same corporations. The "carrier" of the virus of new technology is not the foreign individual but the foreign corporation. (Findlay 1978b p.4)

Given that there is most certainly now, and probably have been, ample "carriers" of technology across economic borders, I agree with the assumption that knowledge

[20]See Fagerberg (1994) for a discussion of the role of technology in the determination of international differences in growth rates.

and technology are indeed public goods. If this is true however, there must be an impediment to the transfer of technology. Essay one as well as Borensztein, DeGregorio, and Lee (1998), and Xu (2000) provide evidence that a sufficient level of human capital is needed to absorb technology—this is no doubt one factor. But are there more? Barro and Sala-I-Martin (1999 chapter 12) provide a list of explanatory variables which have been used in cross-country growth equations by various authors. Along with various measurements of education and human capital they list tariff rates, measures of political risk and political instability, government expenditures (as well as separate measures for war and defense expenditures), investment rates, and financial development measures. What do these measures have in common? Upon first glance it would seem that they all represent a cost or benefit of doing business in a country. An educated workforce is more productive. Tariffs make it more expensive to obtain foreign inputs. An unstable political structure increases the expected cost of doing business in a particular country. Government expenditures, if spent on infrastructure will benefit commerce. High investment rates are a sign of a growing prosperous economy. A well-developed financial market decreases the cost of capital.

In terms of the costs and benefits associated with adopting a particular technology consider the following from Baumol:

> Ever since the beginning of the Industrial Revolution and undoubtedly earlier, there has existed a group of innovative entrepreneurs who have found it profitable to use their talents for the innovative dissemination of technology. As Joseph Schumpeter implies, finding a new place in which to use an invention is itself an innovative act, and frequently the resulting transfer must be accompanied by product or process innovation, as when

> it is adapted to a different climate or to a new market with its particular consumer tastes, and so on. (Baumol 1994 p.76)

Such a statement implies that there is a cost associated with adapting a particular technology to a different situation.

Further evidence comes from a theoretical paper by Brezis, Krugman, and Tsiddon (1993) who provide a two-country model in which a new technology is freely available to both countries, yet because of the current economic conditions that exist in each, only one country finds it profitable to adopt the technology.

2.8 Uncovering the Pattern

The previous section suggests that though technology is may indeed be free, there are costs associated with its adoption. What is it then about the technology produced in different countries that make it more or less costly to adopt? For insight, I now turn to economic historians. According to Previant and Passell (1979):

> English experts, commissioned to investigate the rather rude American challenge to British technological leadership, explained the American advances in terms familiar to 20th-century economists: Differences in technology, they believed, were based on differences in the cost of labor. With abundant land available for farming to anyone who could afford the initial investment in clearing and planting, American industry had to pay high wages to keep workers. High wages induced manufacturers to use the most capital-intensive, labor-saving techniques available. Two modern economists, Erwin Rothbarth and H.J. Habakkuk, have expanded this argument, attributing American technology to the scarcity of labor. (p. 98)

Not only was new technology designed around local economic conditions as measured by the scarcity or abundance of endowments, it was also taken from abroad and adapted to local economic conditions. Using data from 1900-1929, Wylie (1989) provides empirical evidence that Canada adapted US manufacturing technology to minimize costs subject to domestic factor prices.

Using the estimated coefficients from an earlier regression, I will now test the hypothesis that a source country's growth effect is dependent upon differences between the source country's and host country's (US) endowments as measured by capital-labor ratios.

Recall from a previous discussion that the effect of FDI from a specific source country varies in the level of human capital. In order to gain an overall measure of the average contribution of a source country's FDI on growth in the US, I follow the convention of previous sections by using the average level of human capital in the sample (18.24) to calculate a growth effect. Then using capital-labor ratios from the Penn World Tables, I calculate the absolute value of the difference between the source country's capital-labor ratio and the capital-labor ratio of the US in 1988 (the midpoint of the sample period). By using the absolute value of this difference I am implying that the costs/benefits of tailoring a particular technology to economies which are more capital-intensive and those which are more labor-intensive are symmetrical. This variable was then regressed on the growth effect variable for each country to test the hypothesis. Although results from this initial regression support the hypothesis, the exact functional form of the independent variable has many possibilities. After testing a variety of functional forms it was determined that the following regression best fit the data:

$$\text{Growth Effect}_C = v + \delta\sqrt{\left|\left(\frac{K}{L^\bullet}\right)_C - \left(\frac{K}{L}\right)_{US}\right|} \tag{2.3}$$

where the independent variable is the square-root of the absolute value of the differences in endowments as measured by capital-labor ratios. Results of this regression are as follows (standard errors in parenthesis):

$$\text{Growth Effect} = \underset{(0.00176)}{.002234} \quad \underset{(0.0000125)}{-.0000358} \sqrt{\left|\left(\frac{K}{L^\bullet}\right)_C - \left(\frac{K}{L}\right)_{US}\right|}$$

$R^2 = .52$

The larger the difference in capital-labor ratios the weaker the growth effect of the source country's FDI. Figure 4 depicts this result graphically. The growth effect is measured on the y-axis with the square-root of the absolute value of the difference between the corresponding source country's capital-labor ratio and the US capital-labor ratio measured on the y-axis. The left to right downward sloping line represents the predicted values from the above regression. Japan and Switzerland have endowments of capital and labor most similar and different respectively to the US. As supported by tests above the are the most distinctly different from the US in terms of their effect on growth. They also reside on the extremes of positive and negative contribution to US growth.

2.9 Testing the Pattern

Though the previous exercise gives insight into the pattern of a source country's effect on growth, with only 7 data points results are not conclusive. However, armed with a hypothesis concerning the pattern of the growth effect and a functional form, additional techniques can be employed for more conclusive evidence.

Recall from the solution of the theoretical model, equation (12), that FDI increases the growth of an economy by lowering the fixed cost in the $F(\cdot)$ function required to invent and setup production of a new intermediate good. The evidence above implies that this fixed cost should be an increasing function (and thus growth a decreasing function) of the difference between the endowments of the source and home economies. This implies the following change in the theoretical solution:

$$\gamma = \frac{1}{\theta}\left[A^{\frac{1}{\alpha}}\varphi F\left(\frac{n^{*}}{N},\frac{n}{N},N,\frac{N^{*}}{N},\sqrt{\left|\left(\frac{K}{L^{*}}\right)_{C}-\left(\frac{K}{L}\right)_{US}\right|}\right)^{1} H-\rho\right] \qquad (2.4)$$

where:

$$\frac{\delta F}{\delta\sqrt{\left|\left(\frac{K}{L^{*}}\right)_{C}-\left(\frac{K}{L}\right)_{US}\right|}} > 0$$

Beyond the discussion and evidence presented above, the theoretical underpinnings of an individual firm's decision to adopt and adapt technology from abroad can be found in Findlay (1978a). In this piece Findlay derives a cost of adaptation curve which is increasing in the distance between the capital-labor ratios of the source and host country. He then demonstrates that a firm compares the costs and benefits so as to adopt and adapt when the benefits outweigh the costs.

Not only is the regression above based only on seven data points, the differences in capital-labor ratios are calculated at the country level. Because capital-labor ratios vary across the US states and across time (the minimum in the sample is 48116.5 for Rhode Island in 1982 with the maximum being Delaware in 1977 at 159998.2) a much more accurate way to address the question is to calculate this difference at the state level for each 5-year period. One way to proceed would be to add seven right-hand-side variables (one variable for each source country) to empirical equation (13) to account for the interaction between FDI and endowment differences. This method, however, would require the use of twenty-one independent variables that measure FDI in some form or another (seven to measure each source-country's FDI, seven for each interaction term between FDI and human capital, and seven to measure endowment differences). The loss of degrees-of-freedom is an obvious concern, but more problematic is the interpretation of twenty-one variables to answer what has been framed as a very simple question: Do endowment differences matter to the growth effects of FDI?

A more direct route to an answer involves utilization of the spatial methods of Case, Rosen, and Hines (1993). Although technically not a spatial econometric problem, the authors' weighting scheme will allow a direct test of whether or not endowment differences matter[21].

In order to accomplish this I simply create a new variable that weights each state's FDI by differences between the capital-labor ratios of state i and the source country c for a given year:

$$D_i = \sum_{c=1}^{7} \frac{\sqrt{d_{ic}}}{\sum \sqrt{d_{ic}}} \cdot FDI_{ic} \quad (2.5)$$

where d_{ic} is the absolute value of the difference between the capital-labor ratios of state i and country c. By using $\sqrt{d_{ic}}$ instead of $\frac{1}{\sqrt{d_{ic}}}$ to weight FDI, I am giving more weight to FDI from sources less similar in terms of capital-labor ratios. This weighting scheme assumes that the new variable, D_i, is measuring the additional cost involved in adapting foreign technology to the local environment. Thus the more foreign firms located in a given state from source-countries less similar to themselves in terms of endowments of capital and labor, the larger D_i will be. The higher a state's D_i the less it will benefit from technology spillovers, translating into slower growth. The new empirical equation is:

$$\gamma_{it} = \beta_i + \eta_t + k_1 E_{it} + k_2 FDI_{it} + k_3(FDI_{it} \times H_{it}) + k_4 D_{it} + k_5 H_{it} + k_6 Y(0) \quad (2.6)$$

where D_i now takes the place of the 14 variables previously represented by the coef-

[21] Case et al. (1993) examines whether the policy decisions of one state have any effect on the decisions of another state. The problem they face is that it is not feasible to include a R-H-S variable for the decisions of each of the other 49 states. Thus the classic spatial econometric problem is determining which states actually have influence on any given state. This is done by testing various factors which link the decision processes of states (for example, geography, demography, economically). In the case of FDI there is no choice to be made as to which source-countries' FDI affects growth. Whereas Case et al. must uncover the mechanism by which states are linked by "guessing" and then testing the various guesses to find the "best" mechanism, I, guided by theory and a-priori results need not play the guessing game and can move directly to estimation of the model.

ficient vectors a and d. The total effect of foreign direct investment on productivity growth in state i at time t becomes $k_1 + k_2 + k_3 + k_4$. The first three coefficients combine to represent the maximum benefit obtainable from FDI given a state's stock of human capital while the last term measures the cost to adapt the technology to the local environment.

In order to estimate equation (2.6), I employ 5-year panels instead of the 3-year panels used above. The panels are constructed for the years 1978-1982, 1983-1987, 1988-1992, and 1993-1997. The variables of growth, FDI, and employment are averages over each 5-year period. $Y(0)$ is per worker GSP in the initial year of the panel. The human capital variable is the percentage of the population with a college degree in the panel's initial year. All variables, except the shock variable, are regressed in log form.

The methods of estimation are Least Squares Dummy Variable estimation (LSDV) and Kiviet's (1995) method of correcting the Least Squares Dummy Variable technique for the possibility of endogeneity (LSDVc). LSDVc is a form of LSDV proposed by Kiviet (1995). Nickell (1981) was the first to point out the now well known result that dynamic panel data models with fixed effects suffer from biases and inconsistent estimators even if the size of the cross-sectional dimension is quite large. Anderson and Hsiao (1981) addressed this problem by estimating a consistent instrumental variable (IV) estimator via first differences with the first difference of the lagged right-hand-side variable (Y(0) in this case) itself instrumented by its second lagged level.

While the Anderson-Hsiao method produces consistent estimators for a large time dimension, most panel data models utilize a time dimension that is small. Kiviet (1995) directly estimates a small-sample correction (small in the time dimension) to LSDV estimation. Adam (1998) combines the small-sample bias estimation provided by Kiviet along with the Anderson-Hsiao method to a STATA routine that allows a direct application to data[22]. The use of these two econometric methods, as well as the construction of the panels, are consistent with essay one and thus allows direct comparisons to be made between the two. Results are presented in Table 3.

All coefficients in the LSDV estimation are of the expected sign and significant at least at the 10% level. The new variable, Ln(SQRTDIST), is negative and significant at the 1% level further supporting the hypothesis that the larger the distance between the capital-labor ratios of the source and host economies, the lower the growth effect. In fact, the threshold from the LSDV regression in this essay (5.72) is much lower than the LSDV threshold in the first essay (15.56). Such a result is due to the new specification of the cost function and suggests the existence of significant costs involved in transferring technology across economies with unlike endowments.

Before moving on to a more detailed analysis of the results, note that potential endogeneity concerning LSDV is addressed through the use of LSDVc as described in the previous section. However, results using LSDV and LSDVc are not directly comparable. This is because LSDVc estimation requires first differences and lags.

[22]Islam (1995) uses an IV estimator based on Chamberlain (1982). Minimum Distance Estimation, as it is called, does not address the potential for small-sample-bias.

Using first differences and lags reduces the time dimension of the panel from T=4 to T=3 (n=192 to n=144). The important result here is that the estimated coefficients do not change substantially from LSDV to LSDVc even with a reduction in the time dimension.

Table 4 gives some sense of the match between each state and its FDI via capital-labor ratios. Values shown are the average distance of a state's FDI as a percentage of its own endowment of capital and labor (averaged over the 4 periods of the sample). The table demonstrates that significant differences exist between endowments of source countries and the US states in which they locate. For example, Rhode Island's foreign investment originates from countries with endowments more that 53% different than those existing in the state. Alabama, Delaware, Idaho, Maine, Mississippi, New Jersey, North Carolina, South Carolina, and Vermont all have a stock of FDI with an average endowment difference of over 40%. The state with a stock of FDI most similar to its own is Kentucky at a difference of 23.54%.

While Table 4 gives a sense of the possible mismatches that exist between the technology used by foreign and domestic firms within the US, it does not provide a basis for quantitative analysis[23]. For this I must return to the results of Table 3. The sign and significance of the coefficient on Ln(SQRTDIST) supports the hypothesis that differences between endowments does indeed matter to the growth effect of FDI from a source country in a given economy. Coefficients also reveal that human capital

[23]This is because the values presented in table 4. are a weighted average of the distance between the capital-labor ratios of a state and the source country while the values used in the regression of equation (2.6) are a state's FDI weighted by the distance. The two are not necessarily correlated.

seems to be less of a concern that demonstrated in essay one, but to what extent has the role of human capital been diminished? In order to address this question, I use the estimated coefficients of Table 3 and solve for the level of human capital needed to overcome the costs associated with any endowment mismatches between the source countries and each state[24]. These calculations are presented in table 5. The calculated threshold for every state exceeded its stock of human capital as measured by the percentage of the population with a college degree. *This implies that on average no state benefited more from its particular mix of FDI than domestic investment, as measured by growth in per worker output, over the period from 1978-1997!*

It is important to clarify that this does not mean that no state benefited from FDI over the period. Or even that no state benefited more from any one source over the period. The important conclusion is that no state had a mix of FDI such that it benefited more from FDI over the period than domestic investment. Overall, results point to endowment differences as the driving force of behind the effectiveness of FDI.

2.10 Conclusion

The earliest neoclassical models of growth (Solow 1956 and Swan 1956) immediately placed technology at the forefront of the growth debate. The models predict that if the rate of technological progress, considered exogenous, slowed to zero, growth

[24] $Threshold_i = \exp[-.0203921 \times \ln(SQRTDIST_i) - \frac{.0311441 \times \ln(FDI)_i}{.0178523 \times \ln(FDI)_i}]$

eventually stops. The models also predict that, because the entire pool of created technology was freely available to all, every economy in the world would eventually converge to a common rate of growth. The importance of technology as the engine of growth and the failure of the model, due to the assumptions concerning the nature of technology, to match an empirical record characterized by major and persistent differences in growth rates across economies led to the models of endogenous growth. These models, which determine the rate of technological progress endogenously, assume that technology is more local than global in nature in nature. While such an assumption is indeed supported by the literature, it seems implausible, especially in the modern global economy, that forces do not exist to spread technology across the globe. Using the multinational corporation as the major force of contagion, this paper resolves the dilemma concerning the nature of technology by introducing a cost of technology transfer into an endogenous model of neoclassical growth. Based upon work by economic historians, I have modeled this cost as an increasing function of the difference between the source economies' and host economy's endowments as measured by capital-labor ratios. I provide the first empirical support that growth, via technology transfer, is dependent upon how closely related are the source countries' and host economy's endowments. The paper also cements the role of the multinational firm as the main carrier of technology across economic borders.

The results of this essay should be quite helpful to the recruitment of foreign firms by advanced economies. Estimated coefficients imply that state recruitment agencies need to explore the compatibility of a potential foreign firm with the domestic environment in order to achieve maximum benefit. Benefits of such recruitment, beyond the immediate increase in employment at higher than average wages (and therefor a larger tax base), will hinge on the transfer of technology from foreign to domestic firms—a benefit which in turn hinges upon the compatibility of technology. My results suggest that no state benefited from their *overall* stock of FDI over the period from 1978-1997.

More importantly, however, are the implications of this essay to the growth prospects of the underdeveloped world. First, with open economies, the concept of convergence is based on the assumption that capital will flow from rich high-capital economies to poor low-capital economies where the marginal product of capital is highest. However, if capital has imbedded within it technology that is labor saving, due to the technology bias as suggested by the economic historians, then why would labor saving capital be sent to economies in which labor is relatively abundant, low skilled, and cheap relative to capital?

Further, if the cost to transfer is a function differences in endowments as measured by capital-labor ratios such technology is likely to be too costly for under-developed economies to adapt. Thus my new model will predict club convergence based on capital-labor ratios. Rich countries will use technology applicable to them (from other rich, capital abundant countries) while poorer countries will use technology (whatever there is of it) applicable to them (from other poor labor-abundant countries and some emerging economies of the world).

But all is not grim for the underdeveloped world. Results of this essay also imply that an economy with a sufficient level of human capital (education) can overcome the costs involved in transferring technology due to endowment differences and escape the poverty trap. With investment in education and more active recruitment of firms from countries that more closely match them in terms of capital-labor ratios (firms from emerging economies) developing economies can climb a ladder to development. One cannot simply transfer the most advanced technology to the least advanced countries. How can one expect the most uneducated remote tribes to use the world's most sophisticated technology? The process will take time but there is hope.

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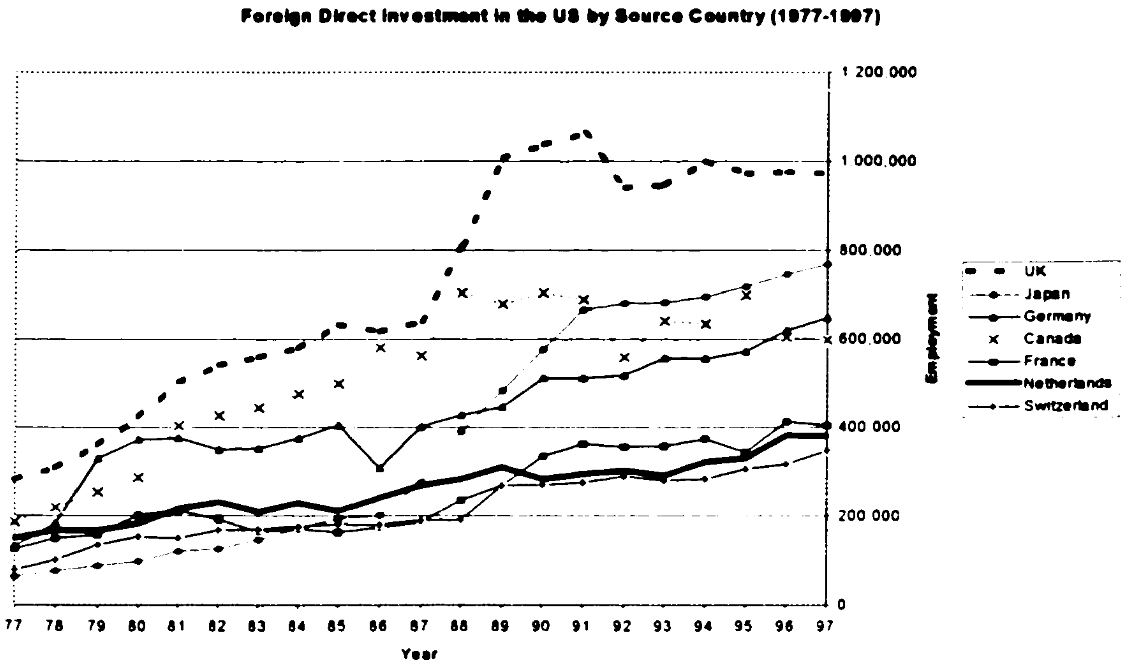

Figure 2.1: FDI in the US by Source Country (1977-1997)

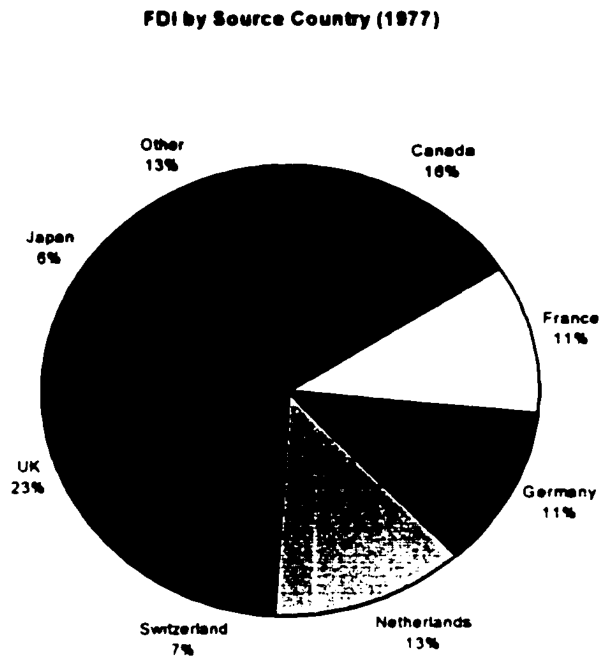

Figure 2.2: FDI by Source Country (1977)

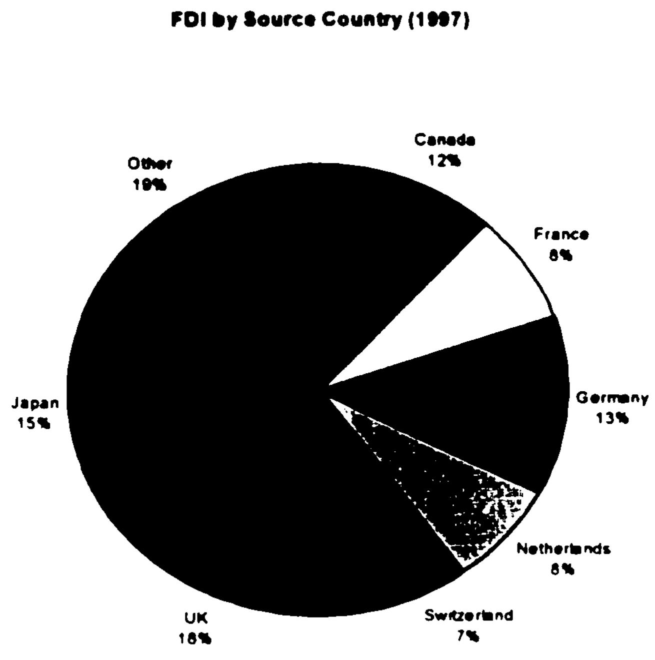

Figure 2.3: FDI by Source Country (1997)

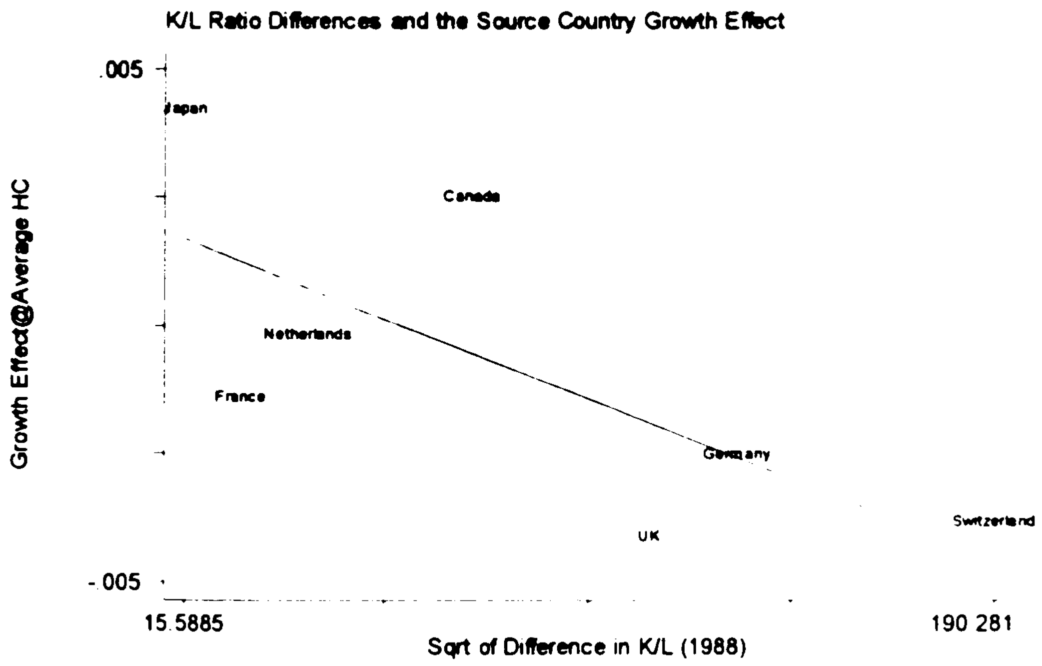

Figure 2.4: Capital-Labor Ratio Differences and the Source Country Growth Effect

Independent variable	METHOD Predicted X's Coefficient (standard error)	Threshold	Imputed X's	Threshold	Unbalanced Panel	Threshold
Y_0	-0 0734124***		-0 0690099***		-0 0706572***	
	0 0136935		0 0132792		0 0147793	
COLLEGE	0 1112128***		0 0860808***		0 0721265*	
	0 0396584		0 0386836		0 0444419	
SHOCK	1 165841***		1 358932		1 320521***	
	0 1486453		0 1444149		0 1486602	
EMPLOYMENT	0 0101858		0 0094434		0 0134342*	
	0 0070511		0 0069493		0 0075445	
SWITZERLAND	0 0213555*	11 09	0 0207688*	11 07	0 0132656	11 07
	0 012339		0 0115635		0 013306	
SWITZERLAND*COLLEGE	-0 0088769**		-0 0086391**		-0 0065167	
	0 0044		0 0041303		0 0046909	
GERMANY	-0 0191935*	17 01	-0 0136659	34 56	-0 0222201**	24 68
	0 0113686		0 0099152		0 0114757	
GERMANY*COLLEGE	0 0067735*		0 0038576		0 0069305*	
	0 0040266		0 0035298		0 0040222	
NETHERLANDS	-0 0174415	18 11	-0 010664	18 82	-0 006852	13 31
	0 0108046		0 0089394		0 0115014	
NETHERLANDS*COLLEGE	0 0060215		0 0036336		0 0026467	
	0 003786		0 0031554		0 0040272	
JAPAN	-0 0242456***	12 59	-0 023635***	11 41	-0 0207266**	12 22
	0 0083561		0 0082257		0 0091477	
JAPAN*COLLEGE	0 0095722***		0 0097069***		0 0082806**	
	0 0029766		0 0029362		0 0032784	
UK	0 000796	1 99	0 0128922	8 63	0 0116439	6 33
	0 0158105		0 0154215		0 0185207	
UK*COLLEGE	-0 0011571		-0 0059827		-0 0063096	
	0 0056058		0 005464		0 0064993	
CANADA	-0 0030981	5 30	-0 0220796	13 19	-0 0050312	9 44
	0 0149629		0 0138817		0 0169064	
CANADA*COLLEGE	0 0018567		0 0085603*		0 0022406	
	0 0063122		0 0049426		0 0059708	
FRANCE	-0 0030829	69 25	0 0000327	1 06	0 0032097	6 25
	0 0139193		0 0118641		0 0149472	
FRANCE*COLLEGE	0 0007275		-0 0005379		-0 0017514	
	0 0048776		0 0041924		0 0052267	
R^2	.42		.47		.53	
Joint Significance						
SWITZERLAND	***		***		*	
GERMANY			***		**	
NETHERLANDS						
JAPAN	***		***		***	
UK			***		***	
CANADA			*			
FRANCE						

* Significant at the 10% level
** Significant at the 5% level
*** Significant at the 1% level
Notes State specific variables, time variables, missing data mechanisms, and constant terms are not reported

Table 2.1: Source Country FDI and Per Capita GDP Growth (1977-1997)

Imputed Data

SWITZERLAND	SWITZERLAND						
GERMANY	*	GERMANY					
NETHERLANDS	***	**	NETHERLANDS				
JAPAN	***	***	***	JAPAN			
UK	-	-	***	***	UK		
CANADA	***	***	*	***	***	CANADA	
FRANCE	**	-	-	***	*	**	FRANCE

Predicted Data

SWITZERLAND	SWITZERLAND						
GERMANY	***	GERMANY					
NETHERLANDS	***	-	NETHERLANDS				
JAPAN	***	**	***	JAPAN			
UK	-	*	-	***	UK		
CANADA	***	-	-	-	***	CANADA	
FRANCE	**	-	-	***	-	**	FRANCE

Unbalanced

SWITZERLAND	SWITZERLAND						
GERMANY	-	GERMANY					
NETHERLANDS	**	**	NETHERLANDS				
JAPAN	***	***	*	JAPAN			
UK	*	**	***	***	UK		
CANADA	**	**	-	-	***	CANADA	
FRANCE	-	-	*	***	**	**	FRANCE

* Significant at the 10% level
** Significant at the 5% level
*** Significant at the 1% level
- not significantly different

Notes: Each country's growth effects are evaluated at the average stock of human capital in the sample and then t-tests are performed which test whether the effects are significantly different from one another. For example, the * in the first element of the table indicates that the growth effect of Switzerland and Germany differ from each other with at the 10% level.

Table 2.2: Testing Differences Between the Growth Effects of Source Countries

	METHOD	
	LSDV	LSDVc
Independent variable	**Coefficient (standard error)**	
ln(Y_0)	-.0842367***	-.12938032***
	(.0122326)	(.0157992)
ln(COLLEGE)	.0865322**	.09661605***
	(.0243006)	(.0346537)
ln(FDI)	-.0311441*	-.05758648**
	(.01734)	(.0264554)
ln(FDI)xln(COLLEGE)	.0178523***	.02558443***
	(.0061493)	(.0097149)
SHOCK	.6393598***	.63908904***
	(.1121765)	(.2208663)
ln(EMPLOYMENT)	.0215034***	.03932219***
	(.0068409)	(.0094033)
ln(SQRTDIST)	-.0203921***	-.00482285**
	(.0046236)	(.0022845)
R^2	.62	0.60

* Significant at the 10% level
** Significant at the 5% level
*** Significant at the 1% level

Table 2.3: Source Country FDI and Per Capita GDP Growth (1978-1997)

State	Average Difference	State	Average Difference
Alabama	41.67%	Nebraska	36.27%
Arizona	27.97%	Nevada	32.97%
Arkansas	34.11%	New Hampshire	39.26%
California	28.25%	New Jersey	40.35%
Colorado	31.34%	New Mexico	39.68%
Connecticut	36.94%	New York	32.80%
Delaware	44.31%	North Carolina	42.77%
Florida	39.31%	North Dakota	29.03%
Georgia	33.85%	Ohio	32.07%
Idaho	41.12%	Oklahoma	28.00%
Illinois	34.40%	Oregon	36.10%
Indiana	24.21%	Pennsylvania	38.37%
Iowa	26.68%	Rhode Island	53.90%
Kansas	26.57%	South Carolina	48.82%
Kentucky	23.54%	South Dakota	31.78%
Louisiana	34.49%	Tennessee	35.93%
Maine	40.75%	Texas	26.87%
Maryland	29.59%	Utah	35.76%
Massachusetts	37.74%	Vermont	47.12%
Michigan	27.02%	Virginia	32.10%
Minnesota	32.19%	Washington	29.11%
Mississippi	49.77%	West Virginia	24.59%
Missouri	30.67%	Wisconsin	32.05%
Montana	34.58%	Wyoming	27.47%

$$Average\ Distance_i = \frac{\sum \sum \frac{FDI_c}{\sum FDI_c} d_{ic}}{4}$$

where d_{ic} is the absolute value of the difference between the capital-labor ratios of state i and country c

Table 2.4: Average Distance of FDI as a Percentage of Endowments (1978-1997)

State	Threshold	State	Threshold
Alabama	34 56%	Nebraska	29 51%
Arizona	35 38%	Nevada	33 87%
Arkansas	34 72%	New Hampshire	37 04%
California	34 86%	New Jersey	37 09%
Colorado	33 48%	New Mexico	32 48%
Connecticut	35 64%	New York	35 79%
Delaware	72 36%	North Carolina	37 89%
Florida	34 87%	North Dakota	29 64%
Georgia	36 36%	Ohio	34 77%
Idaho	32 88%	Oklahoma	33 88%
Illinois	34 43%	Oregon	32 06%
Indiana	35 94%	Pennsylvania	35 18%
Iowa	32 57%	Rhode Island	35 24%
Kansas	32 61%	South Carolina	40 39%
Kentucky	36 08%	South Dakota	29 65%
Louisiana	36 10%	Tennessee	37 31%
Maine	37 76%	Texas	36 21%
Maryland	34 25%	Utah	33 90%
Massachusetts	34 81%	Vermont	33 00%
Michigan	34 36%	Virginia	34 95%
Minnesota	33 87%	Washington	33 09%
Mississippi	32 43%	West Virginia	37 90%
Missouri	32 91%	Wisconsin	33 51%
Montana	30 25%	Wyoming	32 40%

$$\text{Average Distance}_i = \frac{\sum \sum \frac{FDI_c}{\sum FDI_c} d_{ic}}{4}$$

where d_{ic} is the absolute value of the difference between the capital-labor ratios of state i and country c

Table 2.5: Implied Human Capital Threshold Given D_i (1978-1997)

Chapter 3

Blessings and Curses: A Spatial Analysis of the Growth Effects of Foreign Direct Investment in the United States

We're all suffering from winner's curse.
–William Gunther, University of Alabama state economy analyst describing the aftermath of Alabama's successful wooing of Mercedes[1].

The real winner in the Mercedes plant deal was not Alabama, but rather Tennessee.
–Federal Reserve Bank of Atlanta economist Thomas J. Cunningham, onAlabama's 1993 winning bid for a new Mercedes plant[2].

3.1 Introduction

On September 30, 1993, Mercedes announced that Alabama had won the bidding war for the nation's only Mercedes plant. The announcement ended a highly contested bidding war in which Alabama won by paying $300 million to buy and develop a site, improve utilities, provide for employee training, and buy Mercedes vehicles for state employees. The total expenditures amounted to some $200,000 for each new job. Although the new plant was only to provide 1200 initial jobs, state analysts predicted that the multiplier effects of the new plant would provide somewhere between 15,000 to 17,000 extra jobs for the Alabama economy. The analysts were wrong. Mercedes obtains 35% of its inputs from Germany and only 10 of 71 primary suppliers reside in the state of Alabama. In fact, Michigan and Tennessee, each with 8 primary suppliers seem to have received a major windfall without paying a dime. [3]

If foreign firms bring increased industry and technological know-how, management skills, information, and etc. and if spillovers tend to be local in nature as supported by Jaffe, Trajtenberg, and Henderson (1993) then one would expect geographic proximity to play major role. Thus it is reasonable to assume that a state bordering Alabama, Tennessee for instance, may be the recipient of externalities from Alabama's actions. Such a finding would support regional cooperation in the recruitment of FDI.

This paper will utilize the spatial econometric techniques of Anselin (1992), as applied to economic growth by Reys and Montouri (1999) and (Niebuhr, 2001) and

[3,2,and 1] "O Governor, Won't You Buy Me a Mercedes Plant?" ALLEN R. MYERSON The New York Times September 1, 1996 SECTION: Section 3; Page 1; Column 2.

combine them with econometric panel estimation as demonstrated in Islam (1995), Baltagi (2001) and Sedgley and Elmslie (2000). This paper's use of panel estimation techniques with models of spatial dependence is the first application of its kind to the area of economic growth.

There are two major results in this paper. First, it is demonstrated that the spatial pattern of dependence in the US could either help or hinder the natural tendency for states to converge in per capita output. Second, FDI in one state generates negative externalities to it neighbors. This implies that the recruitment of foreign direct investment in the US is a lose-lose situation for every state.

The remainder of the paper is as follows: Section II reviews the early neoclassical growth models as they relate to the fundamental empirical equation of growth and convergence. Section III presents and discusses models of spatial dependence in the context of economic growth. Section IV describes the data of the two sets that are utilized. Section V presents results and analysis from the two problems. Section VI concludes.

3.2 Growth Empirics and Convergence: A Review

The key feature of the early neoclassical growth models of Solow (1956) and Swan (1956) is their prediction of convergence—the hypothesis that poor economies tend to grow faster than rich economies (in per capita terms of output and/or income) such that there is an equalization over time. The models are termed "neoclassical" because of their use of the neoclassical production function which exhibits constant returns to scale and diminishing returns to each input (usually capital (K) and labor (L)) and it is the use of this production function drives the key result. As more and more capital is added to an existing workforce, the resulting increase in output, though always positive, gets smaller and smaller—growth declines. In poorer economies (where capital is lacking) small increments of additional capital provide large increases in output—growth increases. The two economies converge.

These models, along with others by Ramsey (1928), Cass (1965), and Koopmans (1965) set the course for the barrage of empirical work that would began with Baumol (1986). Driven by the intuitive simplicity and global importance of the convergence hypothesis as demonstrated in the work of early growth economists, the following equation has become the workhorse of empirical growth research:

$$[\ln(y_{iT}/y_{i,0})/T] = a - [(1 - e^{-\beta T})/T] \cdot \ln(y_{i0}) + u_{i0,T} \qquad (3.1)$$

Where the dependent variable is the average growth rate of economy i over the period between 0 and T and $u_{i0,T}$ is a mean zero, normally distributed disturbance term. The intercept is $a = x + [(1\text{-}e^{-BT})/T]\cdot[\ln(y^*)+xt_0]$ with x representing the growth rate of technology and $\ln(y^*)$ the steady-state towards which an economy moves at a rate of B. The absence of subscripts in the equation for a is due to the standard assumptions that each economy shares a common pool of technology $(x = x_i)$ and approaches a common steady-state $(y*_i = y*)$. The coefficient on $(y*_i)$

is the convergence coefficient. In the absence of subscripts in the equation for a (resulting in an intercept that is shared by all economies in the sample) the sign and significance of the convergence coefficient allows a direct test of the neoclassical convergence hypothesis. If convergence is present in the data then poorer economies (those with a lower (y_0) will grow faster than rich economies. This inverse relationship between (y_0) and growth is supported with by a negative and significant convergence coefficient. If the coefficient is positive or not significantly different from zero, the presence of convergence in the data is rejected.

Growth equations specified in the form of equation (1) can be estimated means of non-linear least squares in which the actual coefficient is specified resulting in a direct estimate of the speed of convergence (B). This is the preferred estimation method of growth economists who "take Robert Solow seriously" (Mankiw, Romer, Weil, 1992, p.1) and are specifically focused on obtaining the most accurate estimates of B in attempts to resolve inconsistencies that exist between the Solow model and the real world.[4] When estimating the equation without specifying the functional form the speed of convergence is calculated as: $B = -ln(convergence\ coefficient \cdot T + 1)/T$. The equation without specifying the function form is:

[4]Mankiw et al. (1992) attempt to reconcile estimates of the speed of convergence for US states that, when used to calculate the implied share of capital, do not match actual data from the national income accounts. Another major problem concerning current estimates of the speed of convergence is germane to this paper. Specifically, capital, due to proximity to and homogeneity with other states, should be more mobile across other states than across other countries. This suggests that higher estimates of B should be obtained with state data sets than with country data sets. To this point, results are not consistent with this idea.

$$[\ln(y_{iT}/y_{i,0})/T] = \alpha + \beta \ln(y_{i0}) + u_{i0,T} + other variables \qquad (3.2)$$

The discussion of equation (1) assumed that all $i$economies in the data set shared a common steady-state ($y*_i = y*$). With a common steady-state, the inverse relationship betweeny_{i0} and $y*$ensures convergence—rich economies will grow faster than poor economies. However, if steady states differ across economies the inverse relationship between $y_{i0}$and$y*_i$ can hold for each and every economy in a sample, yet rich economies may grow faster than poor economies. With differing steady-states, growth depends on how far an economy is from its own steady-state. Thus a rich economy that is far from its steady-state will grow faster than a poor economy very close to its steady state. The Solow model allows for economies to have differing steady-states, due to differing parameters involving the growth rate of the population, the rate of technological progress, rate of savings, and the rate of depreciation.

The phenomenon of differing steady-states requires a more exact definition of convergence. The definition of convergence given above—the idea that poor economies tend to grow faster than rich economies such that there is an equalization over time—is called absolute convergence. Conditional convergence occurs when poor countries tend to grow faster than rich countries, relative to their own steady-state.

There are two ways to test for conditional convergence. The first involves selecting a data-set of economies thought to be similar enough to have similar steady-states. Such a data-set (US states, Japanese regions, or OEDC, for example) would actually be testing for both absolute and conditional convergence.

The other method for testing conditional convergence involves the term ***other variables*** in Equation (2). This method allows for the addition of variables that are though to account for differences in steady-state values across economies and include various measures of human capital and schooling, investment, political environment, fertility and population growth rates, among others.[5] A data-set that that produces a significantly negative coefficient on the convergence coefficient after the addition of these types of variables exhibits conditional convergence.

It is now generally accepted that absolute convergence, except when limiting the sample to a set of homogenous economies, does not hold. Conditional convergence, on the other hand, has received so much empirical support that obtaining a negative and significant coefficient on the estimated convergence coefficient has become a pre-requisite for further empirical analysis. Although there does not seem to be a magical undercurrent driving *all* the economies of the world towards equality, the conditional convergence method of empirical growth analysis has provided valuable insights into the variables (and thus the policies best) for increasing growth in the poor economies of the world. By focusing on the variables that can be influenced via policy actions, economies can escape their plight of converging towards steady-states that are below those of the developed economies of the world. After a move to a higher steady-state value, the mechanism described above (the inverse relationship between $y_{i0}$and

[5]Chapter 12 in Barro and Sala-I-Martin (1999) contains a list and explanation of most of the variables used in the literature.

growth) will take over and move the economy towards economic prosperity.

While this discussion does give hope to the poorer economies of the world, some critics, the most notable being Quah (1993, 1996a, 1996b), have questioned whether empirical support in favor of the convergence hypothesis (a negative and significant convergence coefficient) is support for a convergence mechanism. Quah's criticism is that no useful information about the evolution of a variable over time can be obtained from regressions based on reversion to the mean.[6] He argues that the support for convergence could be based solely on a statistical uniformity in the data that has nothing to do with current models of economic growth:

> The empirical results [of Barro and Sala-i-Martin]...and elsewhere show a remarkable clustering of β estimates around a central tendency. That tendency is the magic 2% rate of convergence. The *magic* modifier emphasizes this same value's arising from such diverse geographical and time samples. Perhaps it really is the case that the underlying economic structure across countries and regions is invariant. The stability of this 2%-rate would then call for explanation... Alternatively, it might be that underlying structures truly differ across time and space, but that enough of a uniformity exists to produce this stability. The question is. Is that unifor-

[6]His argument is based on a study by English statistician Sir Francis Galton (The conclusion of which is referred to as Galton's Fallacy). Galton observed that the sons of tall fathers were more likely to be shorter than their fathers while the sons of short fathers were more likely to be taller. Galton used this to infer that, in time, the population would converge to a common median height—an obviously incorrect conclusion. Quah, thus argues that conclusions drawn from the tendency for poor economies to become richer over time, and vice versa suffer from the same flaw. While Galton's conclusion was erroneously drawn his observation of a mean reversion contained information—short families are not likely to stay short forever. A shock to family height (an instance of dwarfism, for example) will not ensure that future generations will be born with the same genetic predisposition to low height. Barro and Sala-I-Martin (1999) present the example of the rankings of professional sports teams. If the number of teams in a league are fixed, then there can be no change in the ranking of the average team over time. (With a 25 league team, for example, the average team will always be ranked 13 with no change in the dispersion of the rankings.) However, regression towards the mean would ensure that under current league rules (the draft system, salary-cap, and profit sharing, for example) bad teams would not be bad forever and the same team would not win the championship every year. In the absence of mean reversion the system may be hindering some teams ability to compete.

> mity related to convergence dynamics in economic growth? (Quah 1996a, p. 1359)

Quah is right to question the stability of the rate of convergence across space. The fact that the estimated 2% convergence rate holds for a group of diverse countries as well as a group of homogeneous and cohesive states should be enough to make any neoclassical growth economist raise a brow. The Solow model, on which neoclassical growth theory is based, predicts convergence as a result of capital flowing from where it is abundant (in terms of capital per person)to where it is scarce. It doesn't take a genius to surmise that capital should be more mobile, and therefore the speed of convergence faster, across states in the US than across the oceans of the world. With this in mind, it is to the topic of space and geography in economic growth that I now turn.

3.3 Growth and Space

Economists as far back as Adam Smith have realized the importance of space and geography on the economic growth of economies:

> Indeed though Adam Smith [1776] is most remembered for his stress on economic institutions, Smith also gave deep attention to the geographic correlates of growth... Smith saw geography as the crucial accompaniment of economic institutions in determining the division of labor. Smith's logic, of course, started with the notion that productivity depends upon specialization, and that specialization depends on the extent of the market. The extent of the market in turn depends both on the freedom of markets as well as the costs of transport. And geography is crucial in transport costs. (Gallup and Sachs, 1999)

It is therefore quite shocking that, except for some sparsely placed papers in the literature of urban economics and regional science, empirical growth economists have chosen to ignore the influence of space on growth. Baltagi (2001) states:

In randomly drawn samples at the individual level, one does not usually worry about cross-section correlation. However, when one starts looking at a cross-section of countries, regions, states, counties, etc. these aggregate units are likely to exhibit cross-sectional correlation that has to be dealt with. (p.195)

I follow Reys and Montouri (1999) by introducing three spatial models, each with their own interpretation in the context of the growth literature, that are applicable to the empirical study of economic growth. Because the traditional methods of empirical growth analysis ignore the possibility of spatial dependence between economies, the implementation of any of the following models is likely to be an improvement. The major difficulty that arises is choosing the model that best fits the nature of the spatial dependence.

The remainder of this section will utilize the vector notation form of equation (2) as follows:

$$[\ln(y_T/y_0)/T] = \alpha + \beta \ln(y_0) + u_{0,T} + othervariables \qquad (3.3)$$

3.3.1 Spatial Error Model

The key feature of the spatial error model is that it assumes economies are influenced by other economies via the error term $u_{0,T}$. Because economies are rarely influenced by only one other economy, it is necessary to devise a system that weights each of the error terms of the other economies in a data set. This is done through the use of a weights matrix, the most common of which, called a contiguity matrix, assigns each element of the matrix a 1 if economy i and economy j share a border and 0 otherwise. All weights are row standardized.[7] Using **W** to assign influence, replace$u_{0,T}$ in equation (3) with:

$$u_{0,T} = \lambda \mathbf{W} u_{0,T} + \varepsilon \tag{3.4}$$

where λ is the scalar spatial error coefficient, ε is an independent and identically distributed disturbance with zero mean and a normal distribution, and $\mathbf{W}u_{0,T}$ is a weighted average of the error terms in bordering economies. Solving for $u_{0,T}$in equation (5) and inserting into (3) yields:

$$[\ln(y_T/y_0)/T] = \alpha + \beta \ln(y_0) + (I - \lambda \mathbf{W})^{-1}\varepsilon + othervariables \tag{3.5}$$

In the spatial error model economies are influenced by border economies only through the error term. In a growth context, a random shock introduced into a

[7] Row standardization occurs by dividing each element in the vector of economy i by the sum of the weights in the vector. For example, if an economy shares a border with 4 states, each of the 4 border economies would receive a weight of .25. The sum of the weights for any individual economy always equals 1 after row standardization.

specific economy will affect growth not only in the state where the shock occurred, but every economy in the system. The strength of the influence be largest in an economy's immediate neighbors and dissipate as it works its way outward from the core (Reys and Montouri 1999). Though regression of equation (6) via ordinary least squares (OLS) yields unbiased estimates, the spatial dependence of the errors yields incorrect standard errors for the estimates. As a result, the model should be estimated using maximum likelihood.

3.3.2 Spatial Lag Model

In the spatial lag model, dependent variables are directly influenced by the independent variables of neighboring units. Using the weights matrix **W** as defined above, equation (3) is rewritten to include a weighted average of the neighbor's growth rate:

$$[\ln(y_T/y_0)/T] = \alpha + \beta \ln(y_0) + \rho \mathbf{W}[\ln(y_T/y_0)/T] + u_{0,T} + othervariables \quad (3.6)$$

where ρ is the scalar spatial autoregressive parameter. Solving for $[ln(y_T/y_0]/T]$ to remove its inclusion on the right hand side yields:

$$[\ln(y_T/y_0)/T] = (I - \rho \mathbf{W})^{-1}[\alpha + \beta \ln(y_0) + othervariables] + (I - \rho \mathbf{W})^{-1} u_{0,T} \quad (3.7)$$

which is estimated via maximum likelihood. The estimate of ρ measures the influence of the growth rate in bordering economies on the growth rate on an individual economy. Alternatively, as pointed out by Anselin(1992) one could think of equation (8) as a spatial filter:

$$[\ln(y_T/y_0)/T](I - \rho\mathbf{W}) = \alpha + \beta\ln(y_0) + othervariables + u_{0,T} \quad (3.8)$$

In terms of the growth literature, the spatial filter view allows focus to be placed on the strength of the convergence coefficient after filtering out the spatial effects (Reys and Montouri, 1999).

3.3.3 Spatial Cross-Regressive Model

The final model, called the spatial-cross-regressive model, involves the insertion of a spatially weighted independent variable into equation (3):

$$[\ln(y_T/y_0)/T] = \alpha + \beta\ln(y_0) + \tau\mathbf{W}(\ln(y_0) + u_{0,T} + othervariables \quad (3.9)$$

While the inclusion of the weighted average of $[ln(y_T/y_0]/T]$ on the right hand side of equation (7) allows for (y_0) to enter into the regression, its impact extends to every other economy via $(I\text{-}\rho\,\boldsymbol{W})$. In equation (10) the term $\boldsymbol{W}(ln(y_0))$ is a weighted average of an exogenous variable and thus no inversion is needed. As a result its influence is limited to direct neighbors as specified by $\mathbf{W}$ (Niebuhr, 2001). The estimate of the coefficient τ is a thus a measure of the local growth effects of residing in a cluster of economies with a particular initial wealth.

3.4 Data

Data from the 48 continental United States is used to test the empirical equation. The growth literature is robust with the benefits of using such a data set. These benefits include the consistent manner in which data is collected across states and the similarity of states in terms of culture, language, legal framework, institutional characteristics and the like. In terms of the study of FDI, these benefits apply. However, if spillovers tend to more local than national in scope as Jaffe et al. (1993) suggests, then a state data set is more appropriate for capturing the growth effects of FDI.

Non-bank employment in the US affiliates of foreign firms comes from *Foreign Direct Investment in the United States: Operations of U.S. Affiliates of Foreign Countries*, which is collected by the Bureau of Economic Analysis and is available beginning in 1977.[8] This essay follows the previous two in that it uses a stock measure of FDI for the US economy using non-bank employment in US affiliates of foreign firms— the employment measure. Using non-bank employment in the US affiliates of foreign firms, a stock ratio is then formed by expressing the employment measure for each source country as a percentage of total employment in the economy. The stock ra-

[8] Available on-line at www.bea.gov.

tio will then be a measure of each source countries foreign control of the domestic economy.

Data for total state employment, Gross State Product (GSP), and the sectoral data used to calculate the shock variable also comes from the Bureau of Economic Analysis.[9] Measures of human capital are taken from Statistical Abstract of the United States for the years 1977-1997.

Growth is measured as the average annual percentage change of Gross State Product (GSP) per worker and is calculated as $\ln(y_i(T)/y_i(0))/T$.[10] Human capital is measured as the percent of population with at least a college degree.

Data is annual for the period 1977-1997, however it is standard in the growth literature to construct panels to remove the effects of the business cycle. The data used in the estimation of the effects of FDI is broken down into 5-year panels for the years 1978-1982, 1983-1987, 1988-1992, and 1993-1997. Data used to estimate the speed of convergence is constructed for the years 1963-1967, 1968-1972, 1973-1977, 1978-1982, and 1983-1986. The panels will be estimated using panel forms of the spatial econometric models of the previous section and the method of Least Squares Dummy Variable estimation (LSDV), which is Ordinary Least Squares estimation (OLS) with time and state dummy variables.[11]

[9] Although the raw data used in estimating the speed of convergence is available from the Bureau of Economic Analysis, to ensure comparability, I utilized data from Sala-I-Martin's web site:www.columbia.edu/~xs23/data.usdat.htm.

[10] GSP assigns product to the state in which it is produced whereas personal income is attributed to the state in which the owner of the input resides. Barro and Sala-i-Martin (1992) show that, empirically, results are similar.

[11] Islam (1995) advocates the use of LSDV estimation in growth models. Such a specification is

Because of the lack of results from spatial dependent econometric models, I begin by estimating the speed of convergence (***B***) for two different data sets. Along with the FDI data set used in the first two essays, I use the data from Barro and Sala-I-Martin (1992) which is covers a different time period (1963-1986) than the FDI data set (1978-1997). Each set is estimated using the three spatial models described above (spatial lag, spatial error, and cross regressive) as well as LSDV. Results are presented in table 1. The results of spatial models often include a lot of information so to simplify the evaluation process I will focus on three main areas – spatial error dependence, fit, and estimates.

Spatial models are employed because one surmises the presence of spatial dependence in the data and so it presence should be the first priority in the evaluation of a model. The presence of spatial dependence is detected via the use of a Lagrange Multiplier (LM) test on the errors. A significant value indicates the presence of spatially dependent errors and the test is the same for both the Spatial Error and Spatial Lag models. Results of these tests for the (1978-1997) data indicate that the absence of spatial dependence with the p-values being [.35] and [.61] for the spatial lag and spatial error models respectively. The LM tests on the (1963-1986) data set, however, indicate that while spatial dependence is absence in the Spatial Error model, it is present in the Spatial Lag model.

While the LM tests seem to suggest the use of the Spatial Error model, the

consistent with the concept of conditional convergence and is equivalent to allowing each economy to have its own steady-state value based upon unobservable differences. Sedgley and Elmslie (2000) extend this analysis to US states.

measures of fit need to be analyzed for conclusive evidence. Results for 3 measures are reported in the tabel—log likelihood test, Akaike Information Criterion (AC) and Schwartz Criterion (SC). While log likelihood measures are comparable across all the models (the higher the value, the better the fit), they do not take into account the loss of degrees of freedom due to the addition of explanatory variables (much like the R^2). The AC and SC measures (the more negative the value, the better the fit) make corrections for the number of independent variables (K) used in the regression and are thus better evaluators of fit. As mentioned in the note at the bottom of the table, spacestat fails to count the spatial autoregressive parameter (λ) as a regressor and so the AC and SC must be recalculated for the spatial lag model by adding one to K in the equations at the bottom of the table. Like the LM tests, the measures of fit support the Spatial Error model as the appropriate specification.

The initial level of income is negative and significant across all model specifications. However, the they differ enough that the choice of model is of great importance to the conclusions that can be drawn about the effects of space on the speed of convergence (calculated in the table as $\boldsymbol{B}$).[12] The baseline $\boldsymbol{B}$ is that calculated using LSDV (no spatial effects included) and is around 7% and 14% per year for the 1978-1997 and 1963-1986 periods respectively.[13] The $\boldsymbol{B}$ estimates for the Spatial Lag and

[12]The equation presented earlier is still valid for calculating the speed of convergence in panels, however, in panel data models T is signified as the number of panels, not total years spanning the data set. For the period 1977-1987, T=4 (4 panels) for the 1963-1986 period, T=5 (5 panels).

[13]Note that these estimates are already much higher than the "magic" 2% mentioned earlier. This is due to the use of LSDV which allows each state to have its own steady-state value without the conditioning for used to test for conditional convergence. (See footnote 12)

Spatial Error models are lower and higher respectively. This implies that depending upon the model chosen, the spatial dependence present in the US economic system is either reinforcing the convergence process (Lag Model) or working against it (Spatial Model). Based on the results of the LM and fit tests, the Spatial Error model is superior. Because the speed of convergence is higher in the Spatial Error model for each data set, the implication is that the spatial dependence was acting to slow the convergence process. Further, analysis is needed to more fully decipher what is happening but this result raises interesting and important questions. If the spatial process is working against convergence, are forces in place such that the spatial effects could eventually repel the convergence entirely and begin to reverse it? Are there regime changes in the way the spatial dependence acts or the form it takes (Error or Lag)? Are these forces a result of history, geography, public policy, or something else all together? Is the dependence acting as a mixed model (Lag+Error) as explained in Anselin (1992)? The tools for answering such questions are available. It is my hope that the profession will take more of an interest in the spatial aspects of economic growth the near future.

The second set of results extends the analysis of FDI presented in the first two essays of this dissertation via the use of spatial models. Essay one established the existence of a human capital threshold, above which, US states would grow faster, as measured by per capital output, from FDI compared to domestic investment. Essay two further supported the existence of the threshold, while demonstrating that complementary between the foreign source and the domestic host, as measured by capital-labor ratios, was an important determinate of the growth effect of FDI. Given the recent increase in state recruitment of FDI, this paper uncovers the ultimate winners and losers of FDI in the US.

The same spatial models and tests as described above are used in the analysis. The only change of note is the addition of an FDI cross regressive variable (and an interaction term) to the RHS of spatial models.

The Spatial Error Model becomes:

$$[\ln(y_T/y_0)/T] = \alpha + \beta\ln(y_0) + (I - \lambda\mathbf{W})^{-1}\varepsilon + \ln\left[\frac{\mathbf{W}[ForeignEmployment]}{TotalEmployment}\right] + othervariables \quad (3.10)$$

with the Spatial Lag Model as:

$$[\ln(y_T/y_0)/T] = \alpha + \beta\ln(y_0) + \rho\mathbf{W}[\ln(y_T/y_0)/T] + u_{0,T} + \ln\left[\frac{\mathbf{W}[ForeignEmployment]}{TotalEmployment}\right] + othervariables \quad (3.11)$$

This transformation is simply the addition of a weighted exogenous variable and, if I assumed no spatial dependence in the errors, could be estimated via OLS or LSDV. However, the results of the previous models support the presence of spatial dependence and thus will be estimated as such. Note that only foreign employment in the neighboring states are weighted and not the FDI measure as described above. This specification allows the measure of bordering FDI to be expressed as a percent of the state's own employment and not of the border states' employment—which may be higher as a percent even though total foreign employment is lower.

Results are presented in Table 2. All LM tests support the removal of spatial dependence via the designated specification. Measures of fit are also inconclusive as to the appropriate model. However, it is important to note that estimated coefficients are very close in terms of sign, significance, and the estimated values themselves. While this sheds no light on the spatial process as discussed previously, if the spatial filter view of Anselin (1992) is taken I can interpret the implications of the estimates and discard analysis of the underlying spatial process. The estimates involving FDI, after all, are the focus of this section.

While the human capital thresholds are similar to those obtained in essay one and essay two, I draw attention to the row labeled *foreign threshold.* The thresholds are interpreted as the human capital required for a state to benefit from border states' FDI. Note that this interpretation is different than for thresholds estimated in the first two essays. The difference resides via the role of the ln(EMPLOYMENT) term. From the host-state's point of view, the location of a foreign firm into the state represents added jobs which, shown by the positive and significant coefficients on ln(EMPLOYMENT) across regressions, is a benefit. Then the ln(FDI) and its interaction term, ln(FDI)xln(COLLEGE), measure the *added* impact of a new foreign job relative to a domestic job. In terms of a border state's FDI measured by the variable $\boldsymbol{W}$ln(FDI), and its interaction term, $\boldsymbol{W}$ln(FDI)xln(COLLEGE), there is no home state job addition. Thus for a state to benefit at all from the border states' FDI, the threshold *must* be met. The lowest estimated threshold of the three models that include the terms is 38.02. No state in the US has a stock of human capital even close to this level. The conclusion is that every state in the US loses from every other state's recruitment of foreign firms!

3.5 Conclusion

The results of this paper extend the literature in two areas economic growth and foreign direct investment. As the first application of a spatial panel data approach to the empirical study of economic growth, I demonstrate that, depending upon the model selection, spatial dependence among US states can either speed up or slow down the convergence process. Further tests are needed, but my results point to the latter. The ultimate answer to this question result is important from a development point of view as, if the spatial dependence system is independent of policy and rooted in geography or history, it may seal the fate of the underdeveloped world—for better or worse—for eternity.

Results also extend the analysis of the first two essays by supporting the existence of a human capital threshold that must be met for FDI to increase the growth of per capita output more than domestic investment. Threshold estimates in this paper are similar to those obtained in the first essay demonstrating the model's robustness to a variety of spatial dependence models. The primary result of this paper, however, is the estimation of a spatial threshold that implies that spillovers from foreign investment in bordering states are negative. That is, when a foreign firm locates in a given state, it may steal the growth effects from neighboring states. Coupled with the results of essay one, some states may find themselves faced with a dilemma in which they don't have the human capital to gain more from FDI than domestic investment, yet may stand to lose even more by standing still. Though this finding may support the increased activities of policy officials to recruit foreign firms into their borders, being right may be coming at a heavy price. Unless officials heed the advice implied by essay two of this dissertation - to choose FDI that is compatible with their own economy—the future of the US in regards to FDI may be described as not a "winner's cures" or a "loser's curse" but simply a "curse".

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Independent variable	GSP 1978-1997				GSP 1963-1986			
	Model Specification							
	LSDV	Spatial Lag ML	Spatial Error ML	Cross Regressive LSDV	LSDV	Spatial Lag ML	Spatial Error ML	Cross Regressive LSDV
	Coefficient (standard error)							
Ln(Y0)	- 083833***	- 0547493***	- 087128***	- 084319***	- 0868833***	- 0783727***	- 111775***	- 120068***
	(015836)	(0100239)	(0111857)	(0205504)	(0140724)	(011616)	(0135876)	(0201696)
Spatial Lag Ln(YT/Y0)		369556***				523654***		
		(0781173)				(0596871)		
Lambda			408397***				578782***	
			(0808341)				(0591213)	
WLn(Y0)				0.001408				0421313
				(0203807)				(0285258)
B	0 0734	0 0818	0 0782	0 0744	0 1360	0 0995	0 1637	0 1834
log likelihood	726 90	737 00	738 27	726 90	738 88	765 13	771 22	740 28
AIC	-1349 80	-1368 01	-1372 53	-1347 80	-1371 77	-1422 25	-1438 43	-1372 57
SC	-1180 41	-1195 36	-1203 14	-1175 15	-1187 29	-1234 30	-1251 96	-1184 61
Corrected AIC		-1368 01	-1370 45			-1422 25	-1434 43	
Corrected SC		-1195 36	-1197 88			-1234 30	-1246 48	
LM Test for Spatial Error Dependence (DF=1)	2558	8758				5 975	0 4418	
[p-value]	[35]	[61]				[01]	[51]	

* Significant at the 10% level
** Significant at the 5% level
*** Significant at the 1% level

Table 3.1: Convergence and Space(1978-1997 and 1963-1986)

Independent variable	GSP 1978-1997				GSP 1963-1986			
	Model Specification							
	LSDV	Spatial Lag ML	Spatial Error ML	Cross Regressive LSDV	LSDV	Spatial Lag ML	Spatial Error ML	Cross Regressive LSDV
	Coefficient (standard error)							
Ln(Y0)	- 063633***	- 0547493***	- 067128***	- 064319***	- 0988633***	- 0783727***	- 111775***	- 120068***
	(015835)	(0100239)	(0111857)	(0205504)	(0140724)	(011616)	(0135876)	(0201698)
Spatial Lag Ln(YT/Y0)		369556***				523654***		
		(0781173)				(0598871)		
Lambda			408397***				578782***	
			(0808341)				(0591213)	
WLn(Y0)				0 001408				0421313
				(0203807)				(0285258)
B	0 0734	0 0618	0 0782	0 0744	0 1360	0 0995	0 1637	0 1834
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