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Foreign Direct Investment, Economic Growth, and the Human Capital Threshold: Evidence from US States*

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Abstract

The United States has experienced a dramatic increase in foreign direct investment (FDI) in recent years. While foreign firms bring immediate benefits of high-paying jobs, data limitations have prevented detailed study on FDI's long-term effects on the states receiving it. By creating a new stock measure of FDI based on employment, we are able to capture these long-term effects. Results demonstrate that FDI has a greater impact on per capita output growth than domestic investment for US states that meet a minimum human capital threshold. Ironically, the most active states in the recruitment of FDI tend to fall below this threshold.

1. Introduction

Between 1978 and 1997, the presence of foreign firms in the United States economy increased dramatically. As detailed by Zeile (1999), employment by foreign firms in the US tripled,[1] GDP attributed to foreign firms increased nine times and total assets of foreign firms in the US increased 20 times. By 1997, 6.3% of US output (up from 2.5% in 1978), valued at $384.9 billion, was produced by firms controlled by non-US entities.

This rise in foreign control corresponded with an increasing bidding war between state and local governments to have foreign plants locate within their borders. Be it Volkswagen in 1977, the firms creating Japan Alley during the 1980s, or the recruitment of BMW and Mercedes-Benz in the early 1990s, states have been actively attempting to top one another's packages in order to woo foreign firms. Foreign companies often provide jobs with higher wages[2] while offering the potential for positive spillovers with the existing state economy that will benefit most of the state's population.

To date, there has been little empirical examination of the welfare effects of foreign direct investment (FDI) in the United States. One exception is Figlio and Blonigen (2000), who discovered that although foreign firms pay higher wages, incentives to attract these firms result in decreased public education expenditures by states. Given that there appears to be an opportunity cost of FDI, we wish to explore the aggregate welfare effects of FDI on the states by asking if there is a benefit to FDI in excess to what would be obtained from a similar level of domestic investment.

To do so, we create a stock measure of FDI and estimate the long-term growth effect of foreign-controlled firms relative to domestic firms. We demonstrate that states with a higher foreign presence grow faster relative to states with a low foreign presence,

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provided that the state has a minimum level of human capital to accompany it. When jointly viewed with the results of Figlio and Blonigen (2000), our results suggest that the lower public education expenditures often associated with state incentives to attract FDI may be preventing states from receiving the full potential benefit that FDI can provide.

2. Literature Review

Knowledge Spillovers and Growth

In determining the long-term effects of FDI, we must account for the potential of spillovers that can accrue beyond the simple creation of jobs. Romer (1986) recognized that knowledge spillovers could be one such unintended consequence of investment decisions taken in a perfectly competitive market. These externalities increased the existing stock of knowledge in proportion to the stock of capital, resulting in an aggregate production function void of diminishing returns. This backbone of endogenous growth models was consequently modified by allowing firms to intentionally invest in research and development in their quest for monopoly profits (Romer, 1987, 1990; Aghion and Howitt, 1992).

Grossman and Helpman (1991) show that knowledge spillovers need not be limited to domestic investment, but can be increased through international trade which has the ability to introduce a country to technology that may not exist within its own borders. The presence of multinational corporations should allow for technology to be transferred between countries through a process of learning by watching. Active participation by employees in the production process will accelerate the rate of diffusion and increase the rate of growth.[3]

For endogenous growth models to be relevant, one must be convinced that knowledge spillovers exist. Jaffe (1986) found that firms performing research in areas dense with other firms undertaking the same activity gain more patents per dollar of investment as well as higher returns on their investment. Jaffe et al. (1993) showed through the use of patent data that knowledge spillovers tend to occur not at the country level, but at the state and SMSA levels. Moreover, these spillovers tend to dissipate slowly over time into neighboring areas. Further evidence of knowledge spillovers between US states as well as metropolitan statistical areas is found in Anselin et al. (1997), Zucker et al. (1998), and Varga (2000).

FDI and Growth

One major avenue for technology to be transferred internationally is through FDI. While FDI provides a great deal of promise, many studies fail to find a positive linkage between FDI and technology spillovers (Blomstrom and Kokko, 1998; Mohnen, 2001). One potential reason for this finding may be the failure of some studies to control for the ability of local firms to absorb foreign technology. Studies controlling for absorption capacity (measured in a variety of ways) do find that increased presence by foreign firms is correlated with increased local firm productivity (Barrios and Strobl, 2002). See Durham (2004) for a general discussion.

If there exists positive technology spillovers from FDI, the effect should be felt through increased growth rates. Most studies on the growth impacts of FDI have focused on developing nations. Haddad and Harrison (1993) found limited evidence of technology spillovers in Morocco. Aitken and Harrison (1999) discovered that a higher foreign presence positively impacts the productivity of Venezuelan-based firms, although wholly owned domestic firms suffer in comparison. Lee and Tcha (2004) analyze the growth effects of FDI on transition economies and find that the marginal contribution of FDI to growth in output per capita is greater than that of domestic investment. Javorcik (2004) finds mixed evidence for Lithuania.

Two studies have found a link between spillover and growth effects of FDI and the level of education of workers as the primary indicator of the capability of local firms to accept and adopt foreign technology through FDI. Urata and Kawai (2000) find education as measured by the secondary school enrollment ratio to be an important determinant of intrafirm technology transfers from Japanese firm FDI to five other Asian countries. Borensztein, DeGregorio, and Lee (1998, hereafter BDL) studied the impact of FDI on a panel of developing countries and found FDI to be more productive than domestic investment when in the presence of a minimum level of human capital (measured as years of secondary schooling) in the host country. In a related paper, Xu (2000) finds that US multinational firms have a positive impact on growth in total factor productivity when the host country meets a minimum human capital threshold level.

Until recently, most work on FDI in the United States has been concerned with the locational decisions of foreign-based firms, with a particular emphasis on their responsiveness to state-sponsored incentives.[4] An exception is the work of Figlio and Blonigen (2000), who study the impact of FDI in South Carolina. The authors show that the introduction of a foreign firm into a South Carolina community increased wages seven times the amount being paid in a community with only domestic firms.[5] Consistent with the above study, Keller and Yeaple (2003) find evidence of spillovers from FDI investment in the United States.

Our paper complements both the endogenous growth and FDI literatures. We derive our estimating equation for FDI's impact on state growth in the United States from a model of endogenous growth that builds on BDL. Because FDI has been shown to be a conduit for technology transfer between advanced countries as in Almeida (1996), Haskel et al. (2002), and Branstetter (2006),[6] we feel that such an approach will allow us to best capture the spillovers FDI can bring to a state. Moreover, our creation of a stock measure of FDI allows us to avoid data limitation issues faced by previous researchers, making this paper the first to measure the long-term growth effects of FDI on American states, supplementing the localized, short-run impacts measured by Figlio and Blonigen (2000).

3. Data and Econometric Issues

Measuring FDI as a Stock

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 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 perpetual 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.[7]

Measuring FDI in the US

The US Department of Commerce considers an investment "direct" when any foreign entity (whether a person, firm, partnership, government, etc.) owns or controls at least 10% of a US firm.[8] This 10% 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% may not seem sufficient to guarantee a foreign entity's control over the operations of the US firm, Graham and Krugman (1991) state that on average a foreign entity controls 78.8% of the domestic firm's equity. Such a large majority makes the 10% threshold inconsequential. Further, the authors claim that the Bureau of Economic Analysis (BEA), 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%. FDI is important to the extent that it measures foreign control of domestic production. 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 in the US, we agree with Graham and Krugman (1991) and favor using nonbank employment in US affiliates of foreign firms.[9] Other measures, such as the total assets under control of foreign-owned firms or the balance of payments, suffer from measurement error. A measure based on total assets will be dominated by assets of financial firms that have no bearing on production, whereas a measure reliant on the balance of payments is dependent on book value, which likely understates current market value. We focus on nonbank employment because foreign banks do not seem to behave in a similar way to other types of foreign firms and are dominated in our sample period by Japanese banks (Graham and Krugman, 1991). Because their inclusion is likely to bias results, we exclude them from our measure.

We collected information on the nonbank employment of US affiliates of foreign firms from *Foreign Direct Investment in the United States: Operations of US Affiliates of Foreign Countries*, published by the BEA for the 20-year period of 1977–97. Our stock measure of FDI is formed as the ratio of nonbank employment in US affiliates of foreign firms to total employment in the state. This stock variable of FDI measures foreign control of the US economy and will proxy for the flow of knowledge-based assets over any time period. Figure 1 compares our stock measure of FDI for the mainland US with the percentage of US GDP produced by foreign firms during our 20-year period.[10] The synchronic movement of the two measures lends further credence that our measure is a valid measure of foreign control of the economy.

Econometric Model

To test the following empirical specification, which is derived from a theoretical model of endogenous growth (see the Appendix), we use data from the 48 contiguous states from 1978–97:

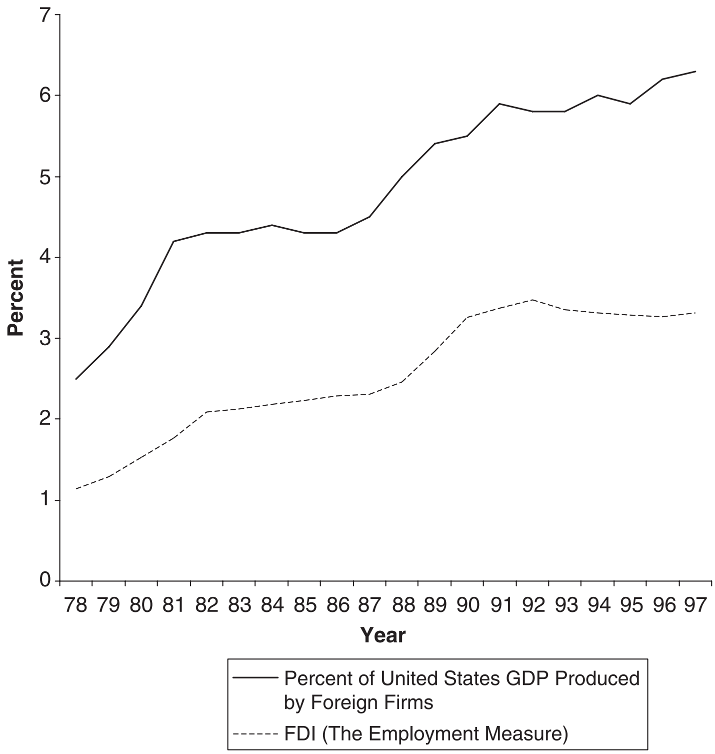

Figure 1. Foreign Direct Investment in the United States, 1978–97

$$\gamma_{it} = \xi_i + \eta_t + \beta_1 E_{it} + \beta_2 FDI_{it} + \beta_3 (FDI_{it} \times H_{it}) + \beta_4 H_{it} + \beta_5 y(0)_{it} + S_{it}. \quad (1)$$

The growth literature is robust with the benefits of using such a dataset. These benefits include the consistent manner in which data are 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 be more local than national in scope as Jaffe et al. (1993) suggest, then a state dataset is also appropriate for capturing the growth effects of FDI.

The variable ξ_i is a vector of state fixed effects[11] and η_t represents the fixed effect of a particular time period. E is the average total employment in a given state over each time period and, as outlined above, FDI is measured as the average share of nonbank employment in US affiliates of foreign firms in total state employment. This specification allows us to measure the total effect of employment (E) on growth as well as the differential effect which arises due to foreign participation in the economies of US states. The inclusion of E (referred to as a scale effect) presupposes that larger economies will grow faster than smaller ones because they have a greater quantity of resources (in this case labor) to devote to the production of new ideas (via research and development, or R&D). It is surmised that because each foreign firm has chosen to produce in the domestic economy, each firm must have *some* advantage (technology, production methods, information, or the like) that allows it to compete on foreign soil.[12] By watching and participating in a foreign firm's activity, domestic firms will not only learn from foreign firms, but also emerge with new ideas. This interaction between foreign and domestic firms allows growth-enhancing ideas to be produced at a faster rate than if they were produced solely by domestic firms. Subsequently, one would expect states with a higher percentage of foreign participation in the domestic economy to experience higher rates of growth.

The variable 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.). The initial level of GDP per worker, $y(0)$, is included to account for the convergence hypothesis—the idea that poor economies should grow faster than rich economies.[13] As advocated by Barro and Sala-i-Martin (1999), a shock variable, S, is added to the equation in order to account for shocks that may affect states differently in order to bring stability to estimated coefficients across time periods.[14]

Nonbank employment in the US affiliates of foreign firms comes from *Foreign Direct Investment in the United States: Operations of US 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 come from the *Statistical Abstract of the United States*.

Growth (γ) is measured as the average annual percentage change of GSP[15] per worker (y) over the time period and is calculated as $[\ln(y_i(T)/y_i(0)]/T$.[16] Human capital is measured as the percentage of the population with at least a college degree.[17] BDL and Urata and Kawai (2000) utilize information on secondary school enrollment as their measures of human capital. Both of these studies analyze the effect of FDI on growth for developing countries. Given differing educational requirements of job markets between developed and developing countries it is more appropriate for our benchmark of education level to be higher. Using data from US multinational enterprises, Xu (2000) finds that the level of human capital in a country dictates the intensity of technology transfer. It may then be expected that more advanced technology is being utilized and transferred through FDI to the US than to developing countries. Firms are not generally attracted to the US market by its large pool of workers with an elementary school education. Moreover, 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.

Data are annual for the period 1978–97; however, it is standard to construct panels in order to remove the effects of the business cycle.[18] Multiple techniques will be employed in order to ensure that the findings are robust. Five-year panels, which are constructed for the years 1978–82, 1983–87, 1988–92, and 1993–97, use the methods of least squares dummy variable (LSDV) estimation, Kiviet's (1995) method of correcting the LSDV technique for the possibility of endogeneity (LSDVc), and seemingly unrelated regressions (SUR) analysis with regional dummy variables. For 10-year panels, constructed for the periods 1978–87 and 1988–97, SUR with regional dummy variables is utilized. The full 20-year period of 1978–97 is also estimated using ordinary least squares (OLS) with regional dummy variables.

LSDV is OLS with time and state dummy variables. Islam (1995) advocates the use of LSDV estimation in growth models. Such a specification is consistent with the concept of conditional convergence which 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 relatively 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 biased 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.[19]

The method of SUR estimates a separate equation for each time period (four equations for the five-year panel and two 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.

4. Results

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, five-year SUR, 10-year SUR, and LSDVc, respectively. 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 terms relative to their own steady state. Of note is the significant difference between the estimated coefficients using the LSDV method of estimation and the others. This finding is consistent with the work of Islam (1995) and Sedgley and Elmslie (2004). The inclusion of an economy-specific intercept term strengthens support for convergence across economies.

The coefficient on $\ln(COLLEGE)$, our measure of human capital, is positive and significant at the 1% level across all estimation techniques. This result highlights the importance of education in the growth process of US states.

Table 1. FDI and Per Capita GDP Growth, 1978–97

Independent variable	*LSDV*	*20-year OLS*	*5-year SUR*	*10-year SUR*	*LSDVc*
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*) × ln (*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

Notes: * Significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level. Time and year/regional fixed effects are included but not reported for all regressions. In the case of 5-year SUR, the system contains 4 equations, one for each 5-year period. In the case of 10-year SUR, the system contains 2 equations, one for each 10-year period. For both 5-year and 10-year SUR, all coefficients except the constant are constrained to be the same for all periods. LSDV and LSDVc are not directly comparable due to differences in the number of observations. See text for discussion. Robust standard errors are reported for 20-year OLS, LSDV, and LSDVc regressions.

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 ln(*FDI*) × ln(*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 than 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.[20] Attention should be given to the stability of this threshold across the various econometric techniques employed. These techniques also allow the data to be separated and estimated over a variety of period lengths: five-year, 10-year, and 20-year periods.[21]

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 1978–97 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. Note 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 23 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 positive coefficient on ln(*EMPLOYMENT*) indicates that a larger level of employment (foreign or domestic) results in a higher growth rate. The two terms,

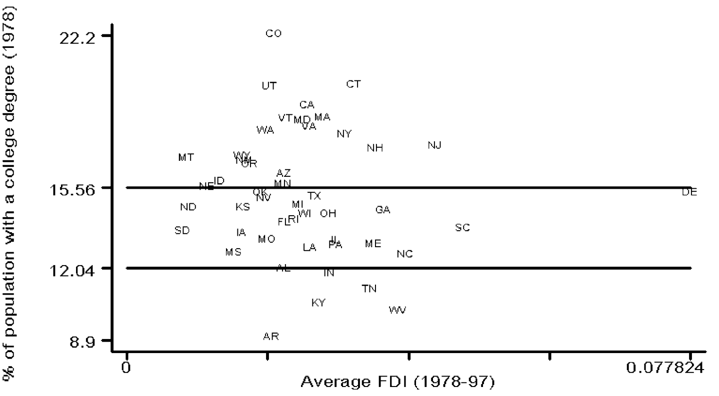

Figure 2. The Human Capital Threshold

ln(*FDI*) and ln(*FDI*) × ln(*COLLEGE*), give the differential effect of foreign employment conditional upon a state's level of human capital. Note that if the coefficients on ln(*FDI*) and ln(*FDI*) × ln(*COLLEGE*) were not found to be jointly significantly different from zero we would 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 0.0196 and the estimated coefficient on ln(*COLLEGE*) is 0.0999. The employment coefficients are interpreted as elasticities; thus a 1% change in employment will increase the growth rate around 0.02% per year. A 1% change in the percentage of the population with a college degree will increase the growth rate of the economy by approximately 0.1% per year. 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 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 0.2% increase in the percentage 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[22] for 1500 jobs, a 0.039% increase in employment. If the money had been spent on the education of 8385 residents, $31,172 would be available for each. 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.

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 $\ln(COLLEGE)$, $\ln(FDI) \times \ln(COLLEGE)$, and $\ln(EMPLOYMENT)$ retain significance at the 1% level. The coefficient on $\ln(FDI)$ 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 coefficient change is around 3% (for $\ln(FDI)$).[23]

5. Conclusion

Because of the inherent difficulty 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 by foreign firms in the domestic country. However, results from previous studies have been unconvincing. We posit that one reason for the lack of consistent evidence of positive spillovers from FDI in many previous studies is the failure to properly account for the social capability of local firms to adopt foreign technology.

Using data from the 48 contiguous United States from 1978–97, this paper demonstrates that foreign direct investment, as measured by foreign control of the US economy in nonbank 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 consider paying more to attract a foreign firm relative to a domestic firm. Evidence on the relationship between FDI and growth at the state level are consistent with increased knowledge spillovers from foreign firms. However, only states that contain a comparatively well-trained workforce have the capacity to take advantage of the presence of foreign technology. BDL found such a threshold to be important for developing countries. Our study confirms that a well-educated workforce is important in realizing the potential growth effects of foreign technology for advanced countries as well.

Appendix: Theoretical Foundations of the Empirical Equation

This model is similar to that presented in BDL which, in turn, relies on the presentation in Chapter 6 of Barro and Sala-i-Martin (1999). Assume an economy that produces a single consumption good according to the following Cobb–Douglas production model:

$$Y_t = AH^{\alpha}K^{1-\alpha}, \tag{A1}$$

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.

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:

$$K = \left[\int_0^N x(j)^{1-\alpha} dj\right]^{\frac{1}{1-\alpha}}, \tag{A2}$$

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:

$$p(j) = A(1-\alpha)H^{\alpha}x(j)^{-\alpha}. \tag{A3}$$

It is assumed that the initial fixed cost 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:

$$\Pi(j)_t = -F(N) + \int_0^{\infty} [p(j)x(j) - x(j)]e^{-rt} dt, \tag{A4}$$

where

$$\frac{\partial F}{\partial (N)} < 0. \tag{A5}$$

The firm maximizes (A4) subject to (A3), yielding:

$$x(j) = HA^{\frac{1}{\alpha}}(1-\alpha)^{\frac{2}{\alpha}}. \tag{A6}$$

Substituting (A6) into (A3) reveals the markup over marginal cost:

$$p(j) = \frac{1}{1-\alpha}. \tag{A7}$$

Assuming zero profits in (A4) due to monopolistic competition and solving for the rate of return, r, yields:

$$r = A^{\frac{1}{\alpha}} \varphi F(N)^{-1} H, \tag{A8}$$

where

$$\varphi = \alpha(1-\alpha)^{\frac{2-\alpha}{\alpha}}. \tag{A9}$$

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

$$U(c)=\int_0^\infty \frac{C^{1-\theta}-1}{1-\theta}e^{-\rho t}dt. \tag{A10}$$

Maximizing (A10) over time and solving for $\dot{C}/C$ yields the equation for the growth rate of consumption, γ_c:

$$\frac{\dot{C}}{C}=\gamma_c=(1/\theta)(r-\rho), \tag{A11}$$

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 (A11) 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 (A8) into (A11) yields the rate of growth of the economy:

$$\gamma=(1/\theta)\left[A^{\frac{1}{\alpha}}\varphi F(N)^{-1}H-\rho\right]. \tag{A12}$$

Equation (A12) 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, we decompose the variable of scale into intermediate goods which are produced by domestic firms (n) and those produced by foreign firms (n^*):

$$N=n+n^*. \tag{A13}$$

It is here that our presentation of the model differs from BDL via the explicit modeling of the differential effects of an increase in N. Dividing (A13) by N results in:[24]

$$\frac{N}{N}=\frac{n}{N}+\frac{n^*}{N}, \tag{A14}$$

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

Multiplying (A14) by N results in:

$$N=N\left(\frac{n}{N}+\frac{n^*}{N}\right). \tag{A15}$$

Rewriting (A5) using (A15) yields:

$$\frac{\partial F}{\partial(N)}=\frac{\partial F}{\partial\left(N\left(\frac{n^*}{N}+\frac{n}{N}\right)\right)}=\left(\frac{\partial F}{\partial\left(\frac{n^*}{N}\right)}+\frac{\partial F}{\partial\left(\frac{n}{N}\right)}\right)<0. \tag{A16}$$

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 (A5) as (A16) allows for an inquiry into whether the introduction of a foreign good has a different impact 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, etc.) that allows it to compete on foreign soil. Subsequently, as the percentage of products produced by foreign firms in the domestic economy rises, so too does the overall stock of knowledge relative to the invention and/or production of the new goods. This knowledge, being different from that being utilized domestically, decreases costs at a faster rate than if it were produced domestically.

Combining (A16), a term to account for the convergence hypothesis (N^*/N) and (A12) results in the final theoretical equation of growth:[25]

$$\gamma = (1/\theta)\left[A^{\frac{1}{\alpha}}\varphi F\left(\frac{n^*}{N}, \frac{n}{N}, N, \frac{N^*}{N}\right)^{-1} H - \rho\right], \tag{A17}$$

$$\frac{\partial F}{\partial\left(\frac{N^*}{N}\right)}, \frac{\partial^2 F}{\partial\left(\frac{N^*}{N}\right)^2} < 0. \tag{A18}$$

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 it 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. This implies (A18), where the costs are lower the larger the gap between N^* and N, and as this gap shrinks, costs decrease 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. 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 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 n/N and 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 for 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 production, 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. 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 will be provoked and growth will be sparked.

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Notes

1. Over this period the share of employment attributed to non-US entities rose from 1.9% to 4.9%.
2. Evidence that foreign firms pay higher wages than domestic firms can be found in Globerman et al. (1994), Howenstine and Zeile (1994), Aitken et al. (1996), and Feliciano and Lipsey (2006).
3. The notion of reverse engineering accelerating technology transfer was first put forth by Findlay (1978).
4. For examples of this strand of research, see Coughlin et al. (1991), Woodward (1992), and Head et al. (1999).
5. Moreover, increases in foreign-controlled employment were found to lead to decreases in government per capita revenues and expenditures, with a particular shift of expenditures away from education and toward transportation and public safety.
6. Counter-evidence has been found by Veugelers and Cassiman (2004) for FDI in Belgium.
7. 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.
8. At this point the US firm is considered a US affiliate of the foreign firm controlling it.
9. This is referred to as the employment measure of FDI.
10. The correlation coefficient between the two measures is 0.9770.
11. The state fixed effects are replaced by regional fixed effects in the case of ordinary least squares and seemingly unrelated regression analyses. The regions (south, midwest, west, and east) are defined as in Barro and Sala-i-Martin (1999).
12. 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 1980s.
13. The idea that there is an advantage to technological backwardness is usually associated with economic historians like Abramovitz (1986). The advantage results from the fact that these economies (states in this case) need not reinvent the existing stock of available (US) technology. The convergence hypothesis is also a result of the neoclassical production function that exhibits diminishing marginal returns to each input holding other inputs constant.
14. The shock variable is given by:

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

where $\omega_{ij,t-T}$ is the weight of sector j in state i's total output at time $t - T$. The second term is the national average annual growth rate of output 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. A low value of this variable would be typical of an economy specializing in sectors that happened to be slowly growing over the time period in question.

15. GSP is in chained 1996 dollars (1996 = 100).

16. GSP assigns the 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.

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

18. For a panel of length T, growth is measured over the entire period from $t = 0$ to $t = T$, whereas all explanatory variables are measured as described in the previous paragraphs in order to follow the convention set forth in BDL, Barro and Sala-i-Martin (1992, 1999), and others. Thus, for a five-year panel from 1988–92, the growth rate is calculated over the entire period, whereas GSP per worker and human capital are measured in 1988. The FDI and total employment variables are averages over the period.

19. An alternative approach would be to follow Islam (1995) which uses an IV estimator based on Chamberlain (1982). Because Islam's IV estimator, called minimum distance estimation, has the potential for small-sample bias, we prefer implementing Kiviet's method.

20. For example, using the results from the LSDV method of estimation yields: $\partial\gamma/\partial \ln(FDI) = -0.0516 + 0.0188 \ln(COLLEGE)$: $\ln(COLLEGE) = 0.0516/0.0188$: $COLLEGE = \exp(2.74) = 15.56$. This is the percent of the population with a college degree required for a state to benefit more from FDI than domestic investment.

21. Additionally, though not reported, the periods were shifted at one-year intervals both forward and back (for example, the five-year techniques were re-tested using the periods 1977–81, 1982–86, 1987–91, 1992–96) to ensure stability. Changes to the estimated coefficients were minimal. All unreported results are available on request.

22. As reported in the 31 May 1998 edition of the *Arizona Republic*. According to an article in the 1 October 1993 issue of the *Los Angeles Times* the incentive included \$77.5 million for infrastructure improvements and \$92 million for development of plant and related buildings. On 1 September 1996, the *New York Times* reported that the total package was closer to \$300 million and included a \$75 million contract by which the state would buy 2500 Mercedes SUVs.

23. Three additional unreported regressions deserve mention. First, LSDVc was performed using $T = 4$ with one-year lags. Secondly, 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. (See page 152 of Baltagi (2001) for a demonstration.) Finally, in the interest of completeness, regressions were also performed using the initial values of all right-hand-side variables (as opposed to period averages). All methods produced estimated coefficients that did not differ substantially in terms of signs or significance.

24. Though we ultimately derive a similar empirical equation, BDL do not incorporate a scale effect but obtain their result by postulating the effects of an increase in n^*/N on $F(\cdot)$. While BDL empirically test for differential effects by including total flow investment over their relevant 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.

25. 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 if intermediate goods do not contribute to diminishing returns. Each new good is neither a direct substitute nor 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 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 empirical investigation concerns the argument (N^*/N). The assumption that the first and second derivatives of $F(\cdot)$ 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 laggard 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.