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Location and the Growth of Nations

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Does a country's long-term growth depend on what happens in countries that are nearby? Such linkages could occur for a variety of reasons, including demand and technology spillovers. We present a series of tests to determine the existence of such relationships and the forms that they might take. We find that a country's growth rate is closely related to that of nearby countries and show that this correlation reflects more than the existence of common shocks. Trade alone does not appear responsible for these linkages either. In addition, we find that being near a large market contributes to growth.

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Do developments in nearby countries matter? More specifically, does a country's long-term growth rate depend on what happens in countries that are close by? A casual look at a map of the world suggests that the answer is yes. Fast-growing countries apparently cluster together, as do slow-growing ones: East Asia is an obvious example of the former, and Sub-Saharan Africa an example of the latter.

Recent theoretical and empirical work generally ignores the impact of location on growth (we discuss some exceptions below). There is considerable indirect evidence on the importance of location, however. Continent or regional dummies often turn up in empirical studies of growth. In addition, studies show that distance matters for variables that are generally thought to matter for growth. Thus, distance is an important explanatory variable in empirical (gravity) models of trade and foreign direct investment and also shows up in models of patenting and studies of migration.

We take a more direct approach in this article and carry out a number of tests that examine whether location matters for growth. We find strong evidence that a country's growth rate is positively influenced by the growth rate of countries nearby and that this reflects more than just the influence of common shocks to the region. It also helps to be near a large market, where size is measured by a country's real output. These results are robust to conditioning on a set of variables commonly used to predict growth rates, a finding that provides information about the channels of these spillovers. However, we are unable to find evidence showing that being near wealthy countries (where wealth is measured by output per worker) has any effect on growth.

The rest of the article is organized as follows. Section 1 discusses reasons why location might matter for growth, including technology and demand spillovers, as well as common shocks. Section 2 reviews related literature. Section 3 describes the data, including our distance measures and the related weights. Our empirical results begin in Section 4, which examines whether neighbors' growth rates matter for growth and also whether the results are sensitive to alternative measures of spillovers (including modifications of our distance-based measures and trade weights). Section 5 investigates whether neighbors' (per worker) income matters for growth, while Section 6 explores the role of neighbors' market size. Section 7 concludes.

1. Why Location Might Matter

At a casual level, it is not hard to find evidence of growth spillovers across countries. For instance, starting in the 1980s, a significant proportion of Hong Kong's manufacturing sector relocated to neighboring areas in mainland China. This shift has been accompanied by rapid growth in the coastal areas of China. Similarly, following several decades of rapid growth in Singapore, firms from that country now routinely set up manufacturing plants in nearby states, and growth in these countries (such as Indonesia) is proceeding at a rapid pace as well. These examples suggest that rapid growth in a country can cause it to run into capacity constraints and turn to another country either for resources or finished goods. This kind of demand would show up in increased trade and foreign investment. Transportation and monitoring costs would tend to keep these effects geographically localized.

Nor are these the only kinds of spillovers one observes; countries that are close together may experience common shocks that affect growth as well. For example, it can be argued that the yen appreciation of the mid-1980s and the early 1990s caused a permanent transfer of Japanese technology and the relocation of some production facilities to East Asia. The choice of relocation appears to have been influenced by distance. Other examples of common shocks are wars (which would affect growth in a specific region) and terms of trade shocks (the increases in oil prices in the 1970s and the reversals in the 1980s) or ecological shocks (the desertification of the Sub-Saharan region of Africa).

Another channel for spillovers is that residents of nearby countries are more likely to have some knowledge of, or have been influenced by, political or economic arrangements in a given country. For example, the organization of the industrial sector in Korea has many similarities to that of Japan, and it is likely that this pattern of industrial organization has influenced the pace of Korea's growth.

It is hard to find formal models that directly address such spillovers. However, we can find models that are indirectly related. Relevant here are models that explain technological spillovers. For instance, in a recent paper, Barro and Sala-i-Martin (1997) develop a model in which growth depends on the discovery of new products or technologies in a few leading economies. Growth in the "follower" countries takes place as a result of technology diffusion, as these countries imitate new technologies created by the leader countries.

Technological spillovers are key in the model of Goodfriend and McDermott (1994 p. 3) as well. In their model, "the degree of convergence or divergence of national per worker products depends upon how well technical knowledge can be absorbed without the hands-on experience that comes with local production. Countries near each other *geographically*, with active commercial relations and a common language and culture, readily absorb technical knowledge from each other" (emphasis added).

The role of proximity in defining the extent of such spillovers can be seen in some recent research on the channels through which technological spillovers occur. An obvious channel is foreign direct investment; foreign firms are likely to bring in new technology when they set up new plants and also to train local workers in the use of these technologies. A recent study by Eaton and Tamura (1994) shows that foreign direct investment is negatively related to distance. In a similar vein, Eaton and Kortum (1994, 1996) use data on patents to show that technological spillovers extend beyond national borders and that this relationship tends to get weaker as the distance between countries increases.

As Grossman and Helpman (1991) point out, international trade also is an important channel for the diffusion of technology, especially to less advanced small open economies. On the import side, suppliers from technically advanced countries train importers in the use of specialized equipment. Producers in the less advanced countries may also learn from the innovations embodied in the imported equipment. On the export side, buyers from advanced economies advise sellers from less advanced countries how to meet market standards, which may require the adoption and use of more advanced technology.[1]

There is a large body of evidence demonstrating that trade depends on distance. Most of these papers estimate a "gravity equation," where bilateral trade is explained in terms of the size of the countries and the distance between them. Bergstrand (1985) presents a general equilibrium model to motivate such a specification as well as some empirical evidence. Frankel and Wei (1993) is a more recent study. Since distance matters for trade, it will matter for technological diffusion through trade as well. Indeed, Frankel and Romer (1996) exploit the relationship between distance and trade to estimate the relationship between trade and growth.

A different motivation is provided by some recent models of imperfectly competitive markets where production is characterized by increasing returns to scale. In such models, a country's ability to grow (as a result of industrialization) depends on its ability to sell to a sufficiently large market. If the domestic market is small so that a single sector cannot make a profit from investing and thus industrializing, growth can be achieved if there is a leading sector, such as the export sector, which creates a sufficiently large market (see, for example, Murphy, Shleifer, and Vishny, 1989a).[2] Since distance appears to be an important determinant of trade, such models suggest that location is likely to matter because it helps determine the effective size of the market available to producers. In other words, it seems preferable to be close to a big economy than a small one.

Growth spillovers may also be motivated by citing another model by Murphy, Shleifer, and Vishny (1989b). Suppose once again that local markets are not large enough to allow any sector to profitably increase its output and that there are no large foreign markets nearby. It is still possible that the *simultaneous* increase in output by many sectors can lead to an increase in income that is large enough to sustain the new higher level of output. Drawing on terminology coined by Rosenstein and Rodan, Murphy, Shleifer, and Vishny

(1989b) describe such a process as a "big push" for industrialization and provide examples of how it may come about. While they set up their model in terms of a closed economy, the demand spillovers that occur when a particular sector grows need not be confined by national borders. For instance, consider a pair of small neighboring economies that trade with each other at relatively low income levels. Analogous to the case of a single economy, the two could embark on a "big push" simultaneously, providing the necessary markets for each other's products.

2. Relationship to Previous Research

DeLong and Summers (1991 p. 487) is the first study we are aware of that takes up the issue of location and growth. In the appendix to their paper they state that "many comparative cross-country regressions have assumed that there is no dependence across residuals, and that each country provides as informative and independent an observation as any other. Yet it is difficult to believe that Belgian and Dutch economic growth would ever significantly diverge, or that substantial productivity gaps would occur within Scandinavia." However, they are unsuccessful in their attempt to find empirical evidence to support this belief. Specifically, they find that the pairwise correlation between the residuals from a growth regression cannot be explained by the distance between these countries.

Chua (1993) postulates the existence of a regional production function, so that the output of a given country depends not only on its own inputs but also on the inputs of contiguous countries (which sometimes includes islands). He finds that regional variables matter, especially the investment-income ratio of the neighbors of the country under consideration. A number of other studies have made use of the proximity metric pioneered by Chua. Ades and Chua (1997) show that political instability in adjacent countries has a negative impact on a country's growth rate. Barro and Sala-i-Martin (1995) show that the initial income level of neighboring countries is marginally significant in explaining growth rates. Finally, Easterly and Levine (1995) use a border dummy variable to analyze the growth experience of Africa. They conclude that spillovers have a large impact on a country's growth: one percentage point more growth in the adjacent country during a given decade translates into own growth of 0.55 percentage points.

Our work generalizes previous work in a number of ways. We use the physical distance between countries as a measure of proximity because it seems to have certain advantages over the use of a dummy variable that is one if two countries have common borders but zero otherwise (which is the case in all the studies cited in the previous paragraph). For instance, Chua's border matrix allows Japan to have an influence on Korea but not on any other country in the data set, such as Indonesia, Thailand, or Singapore. This implies an arbitrary cutoff of influence, while the measure we use allows a country's influence on others to taper off more gradually as the distance between them increases.

Since it is possible to think of more than one metric for proximity, we present some results based on alternative measures as well. The alternatives we examine include some variants on our basic measure, some measures suggested by others, as well as a measure based on the trade between countries. Our results demonstrate that the evidence of spillovers is not limited to the measure of proximity we employ and also that our measure performs reasonably well when compared to the alternatives.

We also test for a wider variety of spillovers than has been the case so far. First, we allow growth in country i to affect growth in country j without restricting the nature of the spillovers involved. We then restrict the kinds of interactions we allow to examine a narrower hypothesis; specifically, we ask whether growth rates in nearby countries are similar because these countries are subject to common shocks. Second, we conduct tests designed to determine whether being near a wealthy country matters (where wealth is measured in terms of per worker income). Finally, we test to see whether the size of the regional economy matters for growth—in other words, whether it is useful to be close to countries with large markets (measured by total output).

The final issue has to do with the specification of the equations we estimate. In thinking about ways to test our basic hypothesis (that location matters for growth) it is natural to think of adding additional explanatory variables to a "standard" growth regression, which is what is usually done. However, proceeding in this way restricts the nature of linkages that our tests can detect. To see why, consider the following example. Suppose that there are two hypothetical countries, Singapore and Indonesia, and that the two are close to each other. Suppose also that Singapore starts growing rapidly, pushing wages there substantially above wages in Indonesia. Following our discussion above, firms from Singapore will invest in Indonesia. Data for Indonesia will show an increase in investment accompanied by an increase in income. The typical growth regression will then explain the growth in income as a consequence of the increase in investment, leaving no room for any influence from abroad (assuming the absence of other channels for spillovers).

While the problem highlighted by our example can in principle be fixed by including direct foreign investment in the regression, the underlying issue is more general. Consider a variant of the example above: instead of firms from Singapore investing in Indonesia, Indonesian firms could raise domestic investment in order to supply the growing market next door. Once again, the impetus would come from abroad, but a growth regression could "explain" growth in Indonesia as a consequence of an increase in investment in Indonesia, leaving little apparent role for international spillovers.

This discussion should be taken to mean not that it is wrong to test for spillovers after controlling for other variables but that the appropriate specification depends on the issues being addressed. In our opinion, the first order of business is to establish the existence of spillovers, regardless of the form they might take. Should such spillovers be found to exist, one can go on to explore the forms they take.

3. Data

Data on output and related variables is from the Penn World Tables database developed by Summers and Heston (1991). We focus on the growth rate of per worker GDP, since we employ the Mankiw, Romer, and Weil (1992) specification as a benchmark in some of our analysis below.[3] The sample size is determined by data availability: our sample contains ninety-three countries over the period 1965 to 1989.

The distance between two countries is measured as the great circle distance between key (or central) cities in the countries. Key cities were determined as follows. If the country belonged to the data set used in Frankel and Wei (1993), we used their choice as the key city. Otherwise, we used the capital city.[4] These distances are used to construct the weighting matrix **W**, whose elements are given by

$$w_{ij} = \frac{1/d_{ij}}{\sum_j 1/d_{ij}}, \qquad i \neq j$$

$$w_{ii} = 0,$$

where d_{ij} is the distance between two cities and we have normalized the matrix so that each row sums to one. Note that our weighting matrix links all the countries in our data set with each other. In a sense, each country belongs to the neighborhood of every other country. However, the relative importance of each country in a particular neighborhood varies inversely with its distance from the country whose neighborhood it is.

We can provide some sense of the characteristics of our distance matrix by comparing it to the border matrix constructed by Chua. (Our matrix is too large to be shown in its entirety.)[5] We do so by presenting some results that show how important the countries that he designates "bordering countries" are in the neighborhoods we construct. It turns out, for instance, that the countries bordering Algeria account for only about 9 percent of the total weight in the neighborhood we construct for Algeria, with the rest of the weight being assigned to countries that do not border Algeria. On average, bordering countries receive 18 percent of the total weight in each of our neighborhoods, while the standard deviation is 12 percent. The share attributable to bordering countries exceeds 40 percent for seven of the ninety-three neighborhoods we construct; the maximum value in our sample is almost 50 percent. The minimum value is 0 (since some countries are defined to have no bordering countries), and there are seven values below 5 percent. In general, then, adjacent countries tend to have a much smaller role when distance is used in the weighting scheme than when the border matrix is used.

4. Does Your Neighbor's Growth Rate Matter?

We begin by asking whether the growth of output per worker in a given country is related to the growth of the other countries in the sample and, in particular, whether this relationship has a spatial element.

The key explanatory variable we employ in this section is obtained by multiplying the weighting matrix shown above by the vector of (per worker) income growth rates. The resulting vector can be thought of as the average growth rate of the neighborhood of each country. To shed some light on the properties of this explanatory variable, the first column of Table 1 shows the top ten and bottom ten country locations identified by this criterion (the remaining two columns are discussed later in this article). With the exception of South Africa, the countries in the highest growth neighborhoods are all in East Asia, led by Malaysia. Countries in Central America and the Caribbean, as well as two African countries, are in the lowest-growth neighborhoods.[6]

Table 1. Location rankings.

Growth	Ranked by: Income per Worker	Market Size
1. Top ten locations		
Malaysia	Belgium	Belgium
Philippines	Germany	Netherlands
Singapore	Netherlands	Germany
Hong Kong	France	France
Taiwan	United Kingdom	Switzerland
Myanmar	Denmark	United Kingdom
South Africa	Norway	Ireland
Japan	Sweden	Denmark
Indonesia	Ireland	Norway
Korea	Switzerland	Austria
2. Bottom ten locations		
El Salvador	Rwanda	Uganda
Costa Rica	Senegal	Lesotho
Colombia	Zimbabwe	Togo
Gambia	Togo	Zambia
Trinidad	Swaziland	Zimbabwe
Dominican Republic	Zambia	Benin
Honduras	Uganda	Ghana
Guatemala	Ghana	Senegal
Barbados	South Africa	Mozambique
Togo	Benin	South Africa

4.1. "Gross" Spillovers

In light of the discussion above, we first look for evidence of spillovers without controlling for the effects of other variables. A simple model of spatial dependence is given by

$$g_i = \rho \sum_{j=1}^{n} w_{ij} g_j + \epsilon_i, \qquad i = 1, \ldots, n \tag{1}$$

or

$$(I - \rho W)G = \epsilon,$$

where g_i is growth of income per worker in country i, W is the $n \times n$ weighting matrix described in the previous section, and ϵ_i is distributed $N(0, \sigma^2)$. In this specification, growth in country i depends on (a weighted average of) growth in other countries, with countries that are nearby having a greater influence than those that are far away. The similarity to the time-series autoregression is obvious; in time-series models what happens in nearby time periods matters, while here what happens in nearby places matters. However, unlike the time series model, the errors here are not independent of the right-side variables; specifically, $\text{cov}(\epsilon, G) = \sigma^2(I - pW)^{-1}$, which is not diagonal. Thus, ordinary least squares estimates

Table 2. Testing for growth spillovers.

Dependent variable: growth rate of output per worker

	All Countries	**All Countries Excluding Newly Industrializing Economies**
Constant	.08	.09
	(.30)[a]	(.37)
Spillovers	.83	.74
	(.00)	(.00)
σ^{b}	.384	.354
AIC[c]	95.7	76.7

a. P values are shown in parentheses.
b. σ is the standard error of the regression.
c. AIC is the Akaike information criterion.

will be inconsistent. Consequently, we estimate (1) using maximum likelihood. The log likelihood is given by

$$L = -\frac{N}{2}\ln \pi - \frac{N}{2}\ln \sigma^2 + \ln|I - \rho W| - \frac{((I-\rho W)G)'((I-\rho W)G}{2\sigma^2},$$

which we optimize using a numerical nonlinear optimization technique in RATS.

In Table 2 we present estimates of this equation over two different samples. The first regression shows that a distance-weighted average of foreign growth rates is highly significant in explaining the growth of output per worker in our sample. The point estimates imply that there are strong regional spillover effects associated with growth; thus, an increase of 1 percent in the distance-weighted growth rate in the rest of the world is associated with roughly 0.8 percent growth in the country under consideration. If anything, these spillovers appear to be too strong. Note that the specification as it stands does not provide any information about the causes of the observed spillovers. These could reflect common shocks, or they could be related to trade or technology, or they could reflect the fact that countries near each other tend to have similar investment rates or levels of education. We will return to this issue below.

Since East Asia has grown at a rapid pace over our sample period, it is natural to ask how large a role that region is playing in the results we have obtained.[7] The second column in Table 2 shows what happens when we reestimate our equation using a sample that excludes the four original newly industrializing economies (NIEs)—Hong Kong, Singapore, South Korea, and Taiwan. The estimated coefficient on the spillover variable falls, though the drop is less than one standard error, and the coefficient is still significant at the 1 percent level.

We also carried out some further tests to determine how sensitive the distance-based spillover measure is to various changes in the specification. First, dropping Japan from the data set (in addition to the NIEs) did not make much difference. Second, we also looked at what the inclusion of continent dummies would do to the estimates in the first column. Dummies for Africa, Europe, Oceania, and South America were insignificant at the 10 percent level and had no noticeable impact on the coefficient of the spillover variable. A dummy for Latin America was significant at 10 but not at 5 percent, while that for Asia was significant at 5 percent. However, the spillover variable continued to be significant at the 1 percent level in all these cases, and the coefficient never fell below 0.65.

These results demonstrate that growth in a given country is strongly related to growth in nearby countries. Further, while our estimates of the strength of this relationship do depend on whether the countries from East Asia are included in our sample, we have also shown that there are significant spillovers even after we take these countries out of our sample.

4.2. Alternative Measures of Proximity

As discussed above, there are a number of ways in which spillovers across countries can occur. It is unlikely that any given measure of proximity will be appropriate for every kind of spillover. For instance, certain kinds of knowledge may flow more easily across countries that trade a lot with each other rather than countries that are next to each other. The procedure used here allows us to test for alternative channels in a simple way—by just substituting a weighting matrix based on the relationship of interest and repeating the estimation.

To see how our finding of growth spillovers is affected by alternative measures of proximity, we first examine what happens when we make some adjustments to our basic measure and then what happens when we use a measure of proximity based on a country's direction of trade.[8]

Our first modification is meant to take country size into account. It is reasonable to expect that the larger the neighboring country, the greater the impact it will have. Following this logic, Easterly and Levine scale the border matrix by the size of the bordering country. By the same token, it seem reasonable to argue that a large country is likely to be less affected by what happens in nearby countries than a small country. Thus, we should adjust for the size of the country whose growth rate we are trying to explain as well. We make both adjustments by multiplying the distance weights by the corresponding ratios of foreign to domestic output. The results are shown in the second column of Table 3. (The original specification in the first column is included for ease of comparison.) The coefficient on the spillover variable in the new specification does not look very different from the old, although both the standard error and the Akaike information criterion favor the new specification slightly. While we have not shown the results here, excluding the NIEs does not materially affect these results.

We now drop the requirement that the distance weights sum to one. Imposing this restriction implies that it is the relative distance between countries that matters; it is also interesting to know how important absolute distance is. The third column shows that as a consequence of this change the spillover variable is significant only at the 6 percent level. However, the model performs slightly worse than the original specification, and it is hard to interpret the magnitude of the coefficient, since the right-side variable no longer has the dimension of an output growth rate. The spillover variable is significant at 5 percent once we drop the NIEs from our data set.[9]

Finally, we show what happens when we use the level of trade between countries as

Table 3. Alternative measures of proximity.

Dependent variable: growth rate of output per worker

	Original Measure	**Adjusting for Relative Country Size**	**Non normalized Weights**	**Trade Weights**
Constant	.08	.06	.27	.16
	(.30)[a]	(.91)	(.00)	(.31)
Spillovers	.83	.86	18.5	.54
	(.00)	(.00)	(.06)	(.05)
σ^b	.384	.378	.407	.411
AIC[c]	95.7	93.3	103.6	105.4

a. P values are shown in parentheses.
b. σ is the standard error of the regression.
c. AIC is the Akaike information criterion.

a measure of proximity. As discussed above, trade appears to be an important channel for spillovers (which is reflected in the substantial literature on the relationship between trade and growth). Further, since distance is an important predictor of bilateral trade, it is natural to wonder how the two measures would do relative to each other. Our weights are constructed in the same way as before: for each country we weigh each foreign growth rate by the amount of trade between two countries (the sum of exports and imports), normalized by the total trade of the country in question. We use trade data for 1985 from the Direction of Trade Statistics of the International Monetary Fund to construct our weights. The final column of Table 3 shows our results; the trade-weighted spillover variable is significant at 5 percent, suggesting that trade generates substantial growth spillovers as well. Note, however, that in terms of either the standard error of the regression or the Akaike Information Criterion, this is the worst specification in the table.[10]

The results presented here show that existence of spillovers across countries is not sensitive to the measure of proximity that we employ. At the same time, the results also suggest that our original measure does a reasonably good job when compared to the alternatives. Only the distance-based measure that adjusts for relative country size leads to a better fitting equation. However, this new measure can be interpreted as the interaction of our growth-rate variable and a market-size variable that is an alternative source of spillovers. (We discuss the market-size variable below.) As we would like to isolate and compare alternative sources of spillovers, rather than mix them, we focus on our unadjusted distance-based measure in the discussion that follows.

4.3. "Net" Spillovers

We now examine whether the regional pattern of growth rates we have found reflects the regional distribution of some (well-understood) determinants of growth rates. To answer this question, we estimate a more general version of equation (1):

$$G = \rho W G + X\beta + \epsilon, \tag{2}$$

or

$$(I - \rho W)G = X\beta + \epsilon,$$

where G is $n \times 1$, W is $n \times n$, X is $n \times k$, β is $k \times 1$, and ϵ is distributed $N(0, \sigma^2)$. This specification allows growth in country i to depend on growth in other countries as well as a set of variables contained in X. Again, because of the simultaneity problem, we estimate this equation using maximum likelihood.[11]

Equation (2) is quite similar to the familiar cross-country growth regression—for instance, those estimated by Barro and Sala-i-Martin (1995) or Mankiw, Romer, and Weil (1992). It differs from such specifications because of the presence of the spillover term on the right side. Consequently, we take the specification estimated by Mankiw, Romer, and Weil (MRW) as a representative version to determine whether spillover effects have a role to play in explaining growth once the usual explanatory variables have been taken into account. Note that—in light of our results above—a finding that distance-weighted growth rates were insignificant in such a specification would not imply an absence of regional patterns in growth rates but that such regional patterns manifested themselves through the other variables in the equation.

Using our data set, we obtain the following estimates for the MRW specification:

$$\begin{aligned} g \;=\; & \underset{(0.4)}{0.30} + \underset{(5.3)}{0.43}\, I/Y + \underset{(2.0)}{0.13}\, Sch \underset{(-1.5)}{-0.44}\, Ngd \underset{(-5.0)}{-0.30}\, InitY, \end{aligned} \tag{3}$$

where the adjusted-$R^2 = .35$, I/Y is the average investment-income ratio, *Sch* is the number of years of secondary education attained, *Ngd* measures population growth (plus technological change and depreciation, assumed to be constant across countries), and *InitY* is initial income per worker. All exploratory variables are in legs.

As it stands, this equation precludes any relationship between growth rates in different countries, except to the extent that the right-side variables exhibit such a pattern. It is possible to test this assumption in a straightforward manner. Here we use a Lagrange multiplier (LM) test[12] to determine whether the null hypothesis represented by equation (3) above can be rejected against the alternative given by equation (2). Using our matrix of distances between countries, the hypothesis that the distance-weighted average growth rate of the countries in our sample does not belong in equation (3) can be rejected quite easily: the computed LM statistic has a marginal significance level of 0.1 percent.

Table 4 presents equations estimated with the spillover variable included on the right side. For ease of comparison, we also include the benchmark MRW specification. A comparison of specifications in the two All Countries columns in Table 4 shows that the coefficients are not significantly altered by the inclusion of the spillover variable, implying that the spillover term is picking up effects unrelated to domestic investment and other variables. The spillover term itself is highly significant in the second column, demonstrating the existence of substantial spatial dependence in growth rates, even after domestic investment,

Table 4. Augmented MRW regressions: Growth spillovers

Dependent variable: growth of output per worker

Countries included:	**All Countries**		**Excluding NIEs**	
Estimated by:	**OLS**	**Maximum Likelihood**	**OLS**	**Maximum Likelihood**
Constant	0.30 (.71)[a]	0.23 (.83)	−0.63 (.41)	−0.58 (.57)
Investment	0.43 (.00)	0.38 (.00)	0.39 (.00)	0.36 (.00)
Schooling	0.12 (.05)	0.11 (.07)	0.06 (.28)	0.06 (.36)
Population growth	−0.44 (.14)	−0.34 (.37)	−0.71 (.01)	−0.61 (.10)
Initial income	−0.30 (.00)	−0.28 (.00)	−0.25 (.00)	−0.23 (.00)
Spillovers		0.68 (.00)		0.51 (.05)
σ^{b}	0.342	0.315	0.313	0.296
$\bar{R}^2$	0.35		0.32	
AIC[c]		65.3		50.7

a. P values are shown in parentheses.
b. σ is the standard error of the regression.
c. AIC is the Akaike information criterion.

schooling, population growth, and initial income have been taken into account. Note, however, that the coefficient on the spatial lag term here is smaller than in the simple model in Table 2 (though the difference is not statistically significant), which suggests that rates of investment, education, and so on are correlated across space as well. The last two columns in the table show what happens when the four NIEs are excluded from the sample. Comparing the first and third columns, the reduction in the estimate for the schooling variable and the increase in the (absolute value of the) population growth variable are quite noticeable. The last column shows that the coefficient on the spillover variable falls, though the drop is less than 1 standard error and the coefficient is still significant at the 5 percent level.

4.4. Do Common Shocks Explain Growth Spillovers?

Our next test is meant to shed light on the source of these linkages. One possibility is that the spatial correlation in growth rates is the result of spatial correlation in the "usual" determinants of growth rates, such as investment, labor force, and so on. Here, we test for a possibility that is the complement to this hypothesis—that is, we ask if the observed correlations could be the result of shocks that are common to geographic regions.

The specification we estimate is

$$G = X\beta + \epsilon, \tag{4}$$

where

$$\epsilon = \rho W\epsilon + \nu.$$

It implies that growth in country i does not depend on growth in country j per se but that the two countries may be subject to common shocks whose impact diminishes with distance. Note that we are imposing the same geographical pattern on shocks that we did on growth rates earlier. Once again, the similarity to the basic MRW equation is obvious; the difference here is that we assume that the error terms in the MRW specification are not well behaved. There is also an LM test that allows us to test the MRW null against the alternative given by equation (4); this time the null is rejected at 11 percent.

While this result is not usually taken to imply rejection, we have gone ahead and estimated equation (4); the results are shown in Table 5. The first column reproduces the MRW estimates for convenience. The second column presents the results when we allow for a spatial pattern in the shocks hitting the system. Here again the coefficients are not very different from the OLS specification. The coefficient on the common shock term is significant at the 5 percent level, which is more favorable to this specification than the results from the LM test. However, the coefficient is no longer significant at the 10 percent level once we exclude the NIEs. This is consistent with Easterly's (1995) finding that when one fits growth regressions, the four NIEs (which are located relatively close to each other) have large residuals associated with them. Note that specifications in the second and third columns in this table do somewhat worse than the corresponding specifications in Table 4 (specifications in the second and fourth columns), implying that the regional patterns in growth rates we observe are better modeled as spillovers than as common shocks.

5. Do Regional Income Levels Matter?

If growth rates of nearby countries matter, do (per worker) income levels? Once again, a casual look at the map suggests that the answer is yes, since countries with similar income levels tend to be clustered together. To obtain a more formal estimate, we construct a geographical variable that measures (per worker) income in the neighborhood, using the same weights as before. As shown in the second column of Table 1, the countries in the ten neighborhoods with the highest income are all in Western Europe, while the countries in the ten neighborhoods with the lowest incomes are in Africa.

The typical equation we estimate here (one which corresponds to the gross spillovers case above) is

$$g_i = \alpha_0 + \alpha_1 y_{0,i} + \alpha_2 \sum_{j=1}^{n} w_{ij} y_{0,j} + \epsilon_i, \tag{5}$$

where ϵ_i is distributed $N(0, \sigma^2)$. In equation (5), $y_{0,j}$ represents initial real GDP per worker in country j, and g_i is the growth rate of income per worker in country i as before.

Table 5. Augmented MRW regressions: Common shocks.

Dependent variable: growth rate of output per worker

Estimated by:	**OLS**	**Maximum Likelihood**	
Sample:	**All Countries**	**All Countries**	**Excluding NIEs**
Constant	0.30	0.46	−0.51
	(.71)[a]	(.71)	(.65)
Investment	0.43	0.37	.36
	(.00)	(.00)	(.00)
Schooling	0.12	0.11	.06
	(.05)	(.09)	(.39)
Population growth	−0.44	−0.36	−0.65
	(.14)	(.39)	(.09)
Initial income	−0.30	−0.27	−0.23
	(.00)	(.00)	(.00)
Common shocks		0.61	0.44
		(.03)	(.17)
σ^{b}	0.342	0.324	.300
$\bar{R}^2$	0.35		
AIC[c]		70.2	53.2

a. P values are shown in parentheses.
b. σ is the standard error of the regression.
c. AIC is the Akaike information criterion.

Following Barro and Sala-i-Martin (1997),[13] we may interpret equation (5) in the context of recent models of technological diffusion. In the simplest versions of this model, some countries lead, and others follow, and no country does both simultaneously. This model yields an equation in which the growth of the follower countries depends upon the gap between them and the leaders (the growth of the leaders is determined by a different model). Our present approach can be interpreted as a generalization of this type of technology diffusion model in which it is assumed that the cost of technological diffusion is inversely related to distance and that all countries, including technology leaders, acquire some technology from abroad. The first of these two assumptions accounts for the use of distance weights, while the second allows for the inclusion of technological leaders on the left side, as well as the inclusion of all countries on the right side.

The estimated equations are shown in Table 6. To facilitate comparison with equations reported elsewhere, we also report the results for the specification where only the spillover variable is included on the right side. As can be seen in the first column of the table, the spillover variable alone does not help predict growth at all. Adding own initial income (the second column) helps somewhat, though the adjusted R^2 is only .02. The third column shows what happens when the variables from the MRW specification are included: the spillover variable is no longer significant.

It is possible to motivate equation (5) in another way as well. Specifically, the restriction

Table 6. Spillovers: The role of per worker income levels.

Dependent variable: growth rate of output per worker

	Gross Spillovers	Gross Spillovers conditional on initial income	Net Spillovers
Constant	−0.77 (.46)[a]	−1.79 (.15)	−0.05 (.97)
Investment			0.42 (.00)
Schooling			0.13 (0.04)
Population growth			−0.37 (.28)
Initial income		−0.11 (.11)	−0.32 (.00)
Spillovers	0.14 (.25)	0.37 (.05)	0.08 (.64)
σ^b	0.422	.418	.343
$\bar{R}^2$	0.00	.02	.34

a. P values are shown in parentheses.
b. σ is the standard error of the regression.

$\alpha_1 = -\alpha_2 < 0$ in equation (5) gives us an error-correction model, in which the growth rate of country i depends positively on the gap between the initial income level of its neighbors and its own initial income. Thus, the lower its initial income relative to the income of countries close by, the faster it will grow. However, imposing this restriction on the specification in the second column of Table 6 leads to a negative adjusted R^2. We also estimated a slightly different version of this specification, in which the growth rate of country i *relative* to the growth rate of its neighbors depends on the difference in initial income levels, and got the same results.

Based on these results, we conclude that there is no evidence of regional convergence in levels, a result we find surprising.[14]

6. Does the Size of Nearby Markets Matter?

Finally, we consider whether the size of nearby economies matters for growth. The basic estimated equation takes the form

$$g_i = \beta_0 + \beta_1 \sum_{j=1}^{n} w_{ij} Y_{0,j} + v_i, \tag{6}$$

where $Y_{0,j}$ represents the (log of the) GDP of country j at the beginning of our sample. Once again, we estimate two additional versions of this equation; the first one also conditions on

Table 7. Spillovers: The role of market size.

Dependent variable: growth rate of output per worker

	Gross Spillovers	Gross Spillovers conditional on initial income	Net Spillovers
Constant	−3.96 (.00)[a]	−5.00 (.00)	−1.97 (.10)
Investment			0.35 (.00)
Schooling			0.11 (.07)
Population growth			−0.05 (.89)
Initial income		−0.15 (.00)	−0.31 (.00)
Spillovers	0.27 (.00)	0.41 (.00)	0.23 (.01)
σ[b]	.394	.378	.332
$\bar{R}^2$	.13	.20	.38

a. P values are shown in parentheses.
b. σ is the standard error of the regression.

initial income in country i while the second one conditions on the remaining variables in the MRW specification. These results are in Table 7. The table shows that being close to a large market does matter for growth and that this result is true no matter which of the three specifications we look at.

In terms of market size, the countries in the ten most desirable neighborhoods are all in Europe (see the third column of Table 1). Note that nine of these countries also showed up in the most desirable neighborhoods when we ranked them in terms of (per worker) income. Similarly, eight of the ten African countries that are located in the neighborhoods with the smallest market size are also in the neighborhoods with the lowest income. This coincidence is surprising in view of our results that the income level of a country's neighborhood does not affect its growth rate while the market size of the neighborhood does. While we have not conducted a detailed examination of the reasons for this difference in results, we do find an interesting difference in how two other groups of countries are ranked in these measures. It turns out that the relatively slow-growing countries in the Caribbean are ranked noticeably higher when the income measure is used than when the market size measure is used. At the same time, the fast-growing countries of East and Southeast Asia end up in more desirable neighborhoods when the rankings are based on market size than when they are based on income.

Before concluding, it is useful to ask if the market-size effect is independent of spillovers associated with rapid growth. For instance, countries near each other could have grown fast because they were near large markets. To answer this question, Table 8 reports alternative specifications in which both variables are included together. Column *a* shows that both

Table 8. The relative roles of market size and growth spillovers.

Dependent variable: growth rate of output per worker

	Gross Spillovers (based on Market Size and Income Growth)	Net Spillovers based on Market Size	Income Growth	Market Size and Income Growth
Constant	−3.16	−1.97	0.23	−1.40
	(.01)[a]	(.10)	(.83)	(.35)
Investment		.35	0.38	0.33
		(.00)	(.00)	(.00)
Schooling		0.11	0.11	0.11
		(.07)	(.07)	(.08)
Population growth		−0.05	−0.34	−.07
		(.89)	(.37)	(.86)
Initial income		−0.31	−0.28	−0.29
		(.00)	(.00)	(.00)
Foreign market size	0.20	0.23		0.16
	(.01)	(.01)		(.12)
Foreign income per worker growth	0.72		0.68	0.58
	(.01)		(.00)	(.02)
σ^{b}	0.342	.332	.315	.310
AIC[c]	71.2		65.3	63.8

a. P values are shown in parentheses.
b. σ is the standard error of the regression.
c. AIC is the Akaike information criterion.

are significant at the 1 percent level when no other variables are included in the equation. (The second and third columns are included for ease of comparison.) The fourth column shows what happens when the MRW variables are added to the first column. The market size variable is significant only at the 12 percent level now. One interpretation is that the effects of market size are being manifested through the MRW variables. Consistent with this interpretation, we find that the correlation between the investment variable and our measure of market size is 0.6, implying that countries near large markets tend to invest a high proportion of their output.[15]

7. Conclusions

In this article we have investigated the importance of location for growth. We have shown that there are substantial growth spillovers across countries using a variety of different specifications as well as a number of different measures of proximity. To begin with, we find strong evidence of linkages across countries in specifications where we do not control for some commonly used predictors of growth. Such specifications seem useful to us because the usual practice of adding new variables to the "standard" growth regression limits the kinds of spillovers one can look for.

We have also presented some results based on alternative metrics. These results show that the evidence of spillovers is not specific to the measure we employ and also that our measure does reasonably well when compared to the alternatives. The comparison with trade weights is worth highlighting. We find that the growth rates of countries located close by are more reliable predictors of a given country's growth rate than are the growth rates of its trading partners. However, it would be incorrect to see distance and trade as competing channels; as mentioned above, distance has been shown to be a significant determinant of trade. Thus, our results provide evidence suggesting that proximity matters for more reasons than just trade.

We find evidence of spillovers even after we restrict the way in which spillovers might arise—that is, even after we control for a standard set of variables used to predict growth, though the estimated magnitudes are smaller. This reduction in magnitudes is consistent with stories in which spillovers take place through the predictor variables (as in our example about investment spillovers above). Further tests to determine whether the linkages we find reflect the effects of shocks that are common to geographic regions show that while such a hypothesis is not entirely at odds with the data, models that allow for more general spillovers fit the data better.

To our surprise, we could not find evidence that the level of income (per worker) in a region matters. In other words, a country's per-worker income does not appear to converge to those of other countries in the same region. However, proximity to large markets does matter, as countries that are near large markets appear to have grown faster over our sample. Further testing shows that spillovers associated with growth are more significant than spillovers related to market size.

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Notes

1. Coe and Helpman (1995) provide evidence on trade and technology diffusion. They study a sample of twenty-one OECD countries and Israel and find that foreign R&D capital stocks have large effects on total factor productivity, particularly in the smaller countries. They estimate that about a quarter of the worldwide benefits of R&D investment in the seven largest economies are appropriated by their trade partners.
2. Murphy, Shleifer, and Vishny (1989a) describe an economy with two equilibria, one with no industrialization and the other with industrialization.
3. We also experimented with per capita GDP, including the use of a specification similar to Barro and Lee (1994) in some of the regressions below. The results involving the distance variables were little changed.
4. We have made one exception to this scheme. It turns out that the capitals of Congo and Zaire are only 21 km from each other, which means that these two countries are measured as being much closer to each other than

any other pair of countries in our sample. Accordingly, we have moved the capital of Congo so that it is more centrally located.

5. Our distance-weights matrix is available on request.
6. To illustrate, in the case of Korea, Japan has a weight of 7.4%, the other NIEs 11.6%, and the rest of Asia 22.4%. By way of comparison, if we use Chua's border matrix, the countries in the top ten neighborhoods are from a wider mix of regions, comprising Japan, Taiwan, Papua New Guinea, the Philippines, South Korea, Singapore, the United Kingdom, Malta, and Yugoslavia. Those in the bottom ten are (in descending order) Chile, Trinidad, Zambia, Swaziland, Gambia, Mauritius, Hong Kong (since it has no adjacent countries), Sierra Leone, Togo, and Malawi. Spearman's rank correlation coefficient for these two alternate rankings is 0.54; thus, the rankings are positively correlated but do not entirely coincide.
7. The role of East Asia in standard growth regressions is explored by Easterly (1995).
8. The following regressions serve as a different kind of check on the robustness of our results, since they involve a different specification. Our dependent variable was the absolute difference between the growth rates (averaged over the 1965 to 1989 period) of each pair of countries in our sample, which gave us a total of 4,278 observations. We regressed this variable on the distance between each pair of countries. We tried a number of different functional forms for the distance measure, including the inverse, the log, and the square root as well as the linear distance. The absolute value of the t-statistics on the distance variable was 6 or larger in each case, though the adjusted R^2 was low.
9. The experiments reported in the first, second, and third columns of Table 3 were also performed using Chua's border matrix. Spillover effects were still found to be highly significant. The distance-based measure outperformed the border measure in all cases, though the differences were not large. The difference between the distance-based and borders-based measures is much more pronounced when the control variables proposed by Mankiw, Romer, and Weil (1992) are included in the estimation.
10. It is worth noting that we get similar results if we use a different set of weights based on trade data for 1972.
11. The log likelihood is given by

$$L = -\frac{N}{2}\ln\pi - \frac{N}{2}\ln\sigma^2 + \ln|I - \rho W| - \frac{((I-\rho W)G - X\beta)'((I-\rho W)G - X\beta)}{2\sigma^2}.$$

Also, note that OLS estimates can still be used to test for the existence of spillovers. This is because the estimated coefficients will be biased only in the presence of spillovers. Thus, a statistically significant coefficient on the spillover variable cannot be explained away by appealing to bias.

12. This test, as well as the one below, is discussed in Anselin and Hudak (1992).
13. Benhabib and Spiegel (1995) estimate similar equations as well.
14. The second column of Table 6 is reminiscent of the results in Barro and Sala-i-Martin (1995) and suggests regional convergence in levels. However, once regional growth rates are added to this equation, the regional income term is no longer significant. Thus, initial income appears to be significant in the second column because it is acting as a proxy for the growth rate (since initial income is a determinant of the growth rate).
15. Foreign market size is not the only variable that is insignificant at conventional levels in the fourth column. Dropping the population growth variable (which has a marginal significance level above 80 percent) leads to the market size variable becoming significant at 10 percent.

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