APPENDICES

Appendix A
Productivity and Wage Determination

Much of the discussion of FDI and its effects on workers in chapter 4 is driven by the notion that workers' wages are determined by the productivity of labor. Furthermore, a firm's profits are maximized when the firm employs workers such that wage equals the value of the marginal product of an additional worker. This appendix provides elementary theoretical derivations of these notions. This entails the use of some mathematics. However, we begin by presenting the basic concepts in plain English.

The idea that wages are determined by the productivity of labor is centered on the following reasoning. A firm will hire an additional worker if and only if it expects that the additional output (the marginal product) from that worker will generate revenue at least equal to the compensation that must be paid to the worker. In other words, the marginal revenue product made possible by the additional worker must be equal to or greater than the marginal cost of employing that worker. (The marginal revenue product is defined as the marginal product times its value per unit, provided the unit value does not fall as output is increased.) Both the marginal revenue product and the marginal cost are expressed in terms of a flow of value per unit of time (e.g., dollars per hour).

A standard assumption is that there are, at least in the short run, diminishing returns to additional hires. That is, the marginal product of each additional worker begins to fall as more and more workers are added to the payroll. A moment's thought will indicate that this must in general be true. At some point, the firm cannot produce any more output no matter how many additional workers are hired, because certain constraints on output (e.g., the work space available in the firm's plants) will become binding. Thus, to maximize profit, the firm will hire additional workers until marginal product falls to the point where the marginal revenue product exactly equals the marginal cost of an additional hire. If all firms behave this way, then labor markets will clear when the marginal cost to each firm of an additional worker (i.e., the compensation paid to that worker) is equal to the value of the marginal product made possible by that worker. The marginal product, in turn, is determined by how productive the marginal worker is.[1]

These ideas can be expressed mathematically as follows. Suppose that total output is given by the following simple and standard production function:

$$Y = AK^{\alpha}L^{(1-\alpha)},$$

where Y is the total output of a firm per unit of time; K and L are inputs of capital and labor, respectively, per the same unit of time; and α is a constant with a value between zero and one. The variable A can be interpreted as the contribution of technology to output; if A rises, then, even holding K and L constant, Y will rise. All of these variables except α can be considered as time dependent, such that $Y = Y(t)$, $A = A(t)$, and so forth. For purposes of this exposition, we assume that the unit value of output (call it p; this is just the price of one item made by the plant) is independent of the level of output. In this case, total revenue R accruing to the firm from output Y will just be equal to this unit value times output: $R = pY$.

The marginal product of labor then is simply equal to the partial derivative of Y with respect to L, given by

$$Y_L = \frac{\partial Y}{\partial L} = (1-\alpha)AK^{\alpha}L^{-\alpha}.$$

The marginal revenue product MR_L made possible by the marginal worker is then given by $MR_L = pY_L$. Also, the second partial derivative of Y with respect to L is negative, implying diminishing marginal returns to labor:

$$Y_{LL} = -\alpha(1-\alpha)AK^{\alpha}L^{-(1+\alpha)} < 0.$$

1. A word of caution is in order here. As the mathematical exposition that follows will make clear, compensation is thus determined by the marginal productivity of labor, not by its average productivity. Official data on labor productivity, however, report average rather than marginal productivity, for the simple reason that average productivity is much easier to measure. But marginal productivity can differ substantially from average productivity. Fortunately, increases in the marginal productivity of labor, under plausible assumptions, imply increases in the average productivity in equal proportion, so that data pertaining to average productivity can be used as surrogates for marginal productivity.

To show that pY_L is equal to the compensation paid to the worker, we assume that the firm maximizes profits, letting profits be given by *P:*

$$P = pY - C,$$

where C is equal to total costs. C can be broken down into capital costs and labor costs. If r is the unit cost (again per unit of time) of capital and w is the unit cost of labor, then $C = rK + wL$.

Maximization of profits requires that, as a first-order condition, the first partial derivatives of P with respect to both K and L be zero. Hence,

$$(pY_K - r) = 0,$$

and

$$(pY_L - w) = 0.$$

The second of these equations implies that $w = pY_L$, the desired result.

It is useful to note that the production function specified above is linearly homogeneous in K and L, so that Euler's equation applies:[2]

$$Y = KY_K + LY_L.$$

Mutiplying by p gives

$$pY = pKY_K + pLY_L.$$

This can be interpreted as follows. Total revenue to the firm consists of two components, one of which is paid to capital (pKY_K) and the other to labor (pLY_L). Dividing the second of these by L gives the compensation per worker, which is again pY_L, or the unit value times the marginal product of labor. The result shows that if each factor of production (capital and labor) is paid at a rate equal to its marginal product multiplied by the unit value of output, then total payments to factors equal total revenues. This result is not general to all production functions, however. It follows from the linear homogeneity of this form of the production function.

Average product per worker (Y/L) is given by

$$\frac{Y}{L} = AK^{\alpha}L^{-\alpha}$$

2. A function f(x) is linearly homogeneous if the following holds: f(ax) = af(x), where a is any constant. In this instance, x can be a vector of variables, i.e., f can be a function of more than one variable. If f is a production function in two variables, e.g., f = f(K,L), then f(aK,aL) = af(K,L), implying constant returns to scale (if, say, a = 2), then the result says that doubling all factor inputs doubles output).

and is not equal to the marginal product (see note 1). In fact, for this form of the production function,

$$\frac{\partial Y}{\partial L} = (1-\alpha)\frac{Y}{L}.$$

Because the coefficient α is not dependent on time, it is clear that changes in marginal productivity over time are equiproportional to changes in average productivity:

$$\frac{\left(\frac{dY_L}{dt}\right)}{Y_L} = \frac{\frac{d\left(\frac{Y}{L}\right)}{dt}}{\frac{Y}{L}}.$$

This result, as indicated in note 1, is of importance because average productivity in practice is much more easily measured than marginal productivity.

What will increase the marginal productivity of labor and hence the compensation of workers? Chapter 2 suggests that technological advances (or simply technological improvements) can do the trick. This and a little more can be demonstrated by taking the first derivative of the marginal productivity of labor with respect to time. Recalling that all of *A*, *K*, and *L* are functions of time, this requires use of the chain rule:

$$\frac{dY_L}{dt} = \frac{\partial Y_L}{\partial A}\frac{dA}{dt} + \frac{\partial Y_K}{\partial K}\frac{dK}{dt} + \frac{\partial Y_L}{\partial L}\frac{dL}{dt}$$

or

$$\frac{dY_L}{dt} = (1-\alpha)K^{\alpha}L^{-\alpha}\frac{dA}{dt} + \alpha(1-\alpha)K^{\alpha-1}L^{-\alpha}\frac{dK}{dt} - \alpha(1-\alpha)K^{\alpha}L^{-(1+\alpha)}\frac{dL}{dt}.$$

Thus, the marginal product of labor, holding other variables constant, increases with technological improvements over time (*dA*/*dt*) and with increases in the stock of capital over time (*dK*/*dt*). The latter implies that the marginal product of labor increases with capital deepening (an increase in the ratio *K*/*L*). This marginal product, again holding other variables constant, also decreases with increases in the number of workers over time (*dL*/*dt*). This is simply a restatement of the point made earlier that there are diminishing marginal returns to labor.

All this simply shows that foreign direct investment to a developing country (or, indeed, to any country) will put upward pressure on wages, not the reverse. Indeed, in a sense, the theory as developed here is not needed to obtain this result. It could have been stated simply that FDI in any country will increase the demand for labor there, and when the demand for anything, labor included, increases, its price rises. And the price of labor is simply the wage paid to labor.

Importantly, what this theory also implies is that, if a firm is to maximize profits, it must hire enough workers so that the value of the marginal product of a worker is equal to the wage paid. This is important because it is widely misunderstood. For example, antiglobalist authors (see, e.g., Greider 1997) have maintained that multinational firms transfer operations to developing countries in order to combine third world wages with advanced nation productivity. The notion seems to be that the firm can make enormous profits by paying workers much less than the value of the product that they produce. This claim is a little vague. Does "productivity" mean the average product of a worker or the marginal product of the worker? If the former, the notion would apply to any production operation (the average product of a worker is higher than the wage paid to that worker in the United States as well as in Mexico; if this were not the case, then there would be zero return to capital invested in the operation). If the latter, then if the firm pays a wage that is less than the value of the marginal product of the worker, the firm simply is not maximizing profits. The firm would do better to continue to hire workers until the value of the marginal product fell to the wage level.

Appendix B
Is Foreign Direct Investment a Complement to Trade?

Erika Wada and Edward M. Graham

What is the nature of the relationship between foreign direct investment-related activities and trade (exports and imports)? Are they complements, such that, all else equal, increases in outward FDI from a home country are associated with increases in that country's exports or imports? Or are they substitutes, in the sense that, all else equal, increases in outward FDI from a home country are associated with reductions in that country's exports? (A reduction in imports is implausible in this case.) Or is there no relationship at all between FDI and trade? These questions have been around for a long time but remain subjects for debate. The reason is that the answer requires separating and assessing the impact of one factor on a variable whose value can be determined by multiple factors.

In the case of commodities, whether two goods are complements or substitutes can depend upon their relative prices. For example, when the price of butter goes up but the price of margarine does not, demand for margarine goes up, because people switch from the more expensive butter to the cheaper margarine. Thus butter and margarine are substitutes. But when the price of butter goes up, demand for bread goes down. People consume bread and butter together, so that when butter is more expensive, not only does consumption of butter fall, but so does that of bread. Bread and butter are thus complements.

It is not so easy to say whether FDI and trade are substitutes or complements. Each represents a different mode of doing business, and it is not easy to associate a single price with either mode. FDI in this instance must be interpreted to mean "economic activity generated by overseas affiliates

Erika Wada is a research assistant at the Institute for International Economics.

of firms based in the home country." However, FDI per se is not a direct measure of this activity, which could be measured in a number of ways, including sales generated by these affiliates, or value added by them, or the value of shipments generated by them. FDI itself, however, is none of these. It is simply the equity capital held by US investors in these affiliates. There is, fortunately, a positive relationship between the total stock of FDI and the economic activity that this stock generates. Therefore, in this exercise, the stock of FDI is used as a surrogate for the activity it generates. With this in mind, what we wish to determine is, in essence, whether production by affiliates of a multinational abroad substitutes for production in its home country or complements it.

The approach taken here is to extend a standard gravity model, originally developed to analyze trade activity as a function of distance, GDP growth, and population growth, to address the question just posed. The data encompass 58 countries that have engaged in significant trade and/or investment with the United States during the years 1983 to 1996.

Using the gravity model, we examine trade and investment activities between the United States and the rest of the world. We limit our examination to trade in manufactured goods and to FDI in the manufacturing sector. We do so because the distinction between the export of a service from the United States and the rendering of a service by a foreign affiliate of a US firm can often be somewhat arbitrary. Thus, a bright line between trade in services and services generated by FDI would be difficult to establish. Focusing only on the manufacturing sector thus eliminates a serious data complication, but at the expense of eliminating services, which account for a growing share of both world trade and world FDI.

The gravity model relating the FDI stock, exports, imports, and the factors that jointly determine them can be specified most simply as follows:

$$\begin{aligned} FDI_{i,t} = {} & \alpha_1 PGDP_{i,t} + \alpha_2 POP_{i,t} + \alpha_3 DISTANCE_{i,t} \\ & + \alpha_4 EXPORT_{i,t} + \alpha_5 IMPORT_{i,t} + \mu \end{aligned} \tag{1}$$

where $FDI_{i,t}$ is the stock of FDI from country j (in this case, the United States) in the manufacturing sector of country i at period t, *PGDP* is per capita GDP of country i, *POP* is the total population of country i, *DISTANCE* is the distance between the capitals of country i and country j, *EXPORT* is the nominal level of manufactured goods exports from country j to country i, and *IMPORT* is the nominal c.i.f. (cost plus insurance and freight) value of manufactured goods imports from country i to country j. Following standard usage, μ represents an error term with normal distribution and with mean $E(\mu) = 0$.

It is fair to question whether equation (1), a simple linear equation, correctly represents the relationships among the variables even if the variables are correctly identified. For example, one might speculate whether the impact of an increase in exports on FDI-related activities is magnified by an increase in the level of imports. Modeling such a relationship would require the inclusion of terms representing higher powers of the independent variables (polynomial terms) and/or cross-product terms. Such a model could more closely fit the data than does equation (1). There could also be a problem with endogenous effects, as discussed below.

The regression specification test (RESET) suggested by Ramsey (1969) can be used to detect the first type of specification error (nonlinear terms) in the model. The underlying reasoning of the test is simple. If the model is linear, adding any polynomial composed of the same independent variables will not increase the explanatory power of the model—any such terms will be statistically insignificant. In this case, the model can be written as

$$y = x\beta + u \tag{2}$$

$$E(u \mid x) = 0 \tag{3}$$

such that adding polynomial terms x^e does not increase the R-squared statistic associated with the regression of x on y implied by equation (2). To test whether this is true, one can simply add the variable x^e to equation (2) and see what the effect is on R squared. However, adding polynomial terms may create a problem of insufficient degrees of freedom. Thus, Ramsey suggested that the fitted value of the dependent variable, $\hat{y}$, can be used as a proxy for the independent variables. Using the Ramsey test, the following specification is tested:

$$\hat{y} = x\hat{\beta} + \alpha_1 \hat{y}^2 + \alpha_2 \hat{y}^3. \tag{4}$$

The null hypothesis, then, is that α_1 and α_2 are jointly insignificant. Using the standard f-test, the result for our model indicates that α_1 and α_2 are jointly *significant*, implying that some nonlinearity is indeed present. Hence, for our data, the gravity model must incorporate at least some first-order nonlinear terms. These can be added by respecifying the model as follows:

$$FDI_{i,t} = PGDP_{i,t}{}^{\beta 1} POP_{i,t}{}^{\beta 2} DISTANCE_{i,t}{}^{\beta 3} EXPORT_{i,t}{}^{\beta 4} IMPORT_{i,t}{}^{\beta 5} \mu \tag{5}$$

where μ is a log-normally distributed error term. Equation (5) can be transformed into a linear equation by taking the natural logarithms of both sides, as follows:

$$\begin{aligned} \log(FDI) = \beta_1 \log(PGDP) + \beta_2 \log(POP) + \beta_3 \log(DISTANCE) \\ + \beta_4 \log(EXPORT) + \beta_5 \log(IMPORT) + \mu. \end{aligned} \tag{6}$$

Using RESET, we again test whether this model neglects some nonlinearity, and the result indicates that it does. To compensate for this, we then add second-order polynomials of the independent variables. This time we find that, although the second-order polynomial compounds of the log of per capita GDP, the log of population, and the log of distance are statistically significant at a 5 percent level of confidence, those of the logs of exports and imports are not. The model is therefore respecified in the following form:

$$\begin{aligned} \log(FDI) &= \beta_1 \log(PGDP) + \beta_2 \log(POP) + \beta_3 \log(DISTANCE) \\ &+ \beta_4 \log(EXPORT) + \beta_5 \log(IMPORT) + \beta_6 [\log(PGDP)]^2 \\ &+ \beta_7 [\log(POP)]^2 + \beta_8 [\log(DIS)]^2 + \mu. \end{aligned} \tag{7}$$

Using this specification, however, we find that the coefficients of the logs of exports and imports, β_1 and β_2 in both equations (6) and (7) are essentially the same. The standard *f*-test indicates no statistically significant difference between them.

Another potential complication in this model is endogeneity: trade and FDI-related activities might be jointly determined. The above specification test indicates that trade and FDI-related activities are related in a nonlinear manner. Further testing indicates that log transformation, a simple way to transform the model from linear to nonlinear form, still leaves some misspecification. This misspecification is likely caused by endogeneity. Endogeneity is a problem, for example, if a US firm at first exports cars to Mexico but later establishes an assembly plant in Mexico, which imports automobile parts from the United States and exports finished automobiles back to the United States. In this case, cause and effect are circular; FDI causes trade and vice versa.

To deal with this endogeneity we apply the instrumental variable method using two-stage least-squares (2SLS) estimation. In essence, the estimated level of trade activities instead of the actual level is used to determine the impact of trade activities on FDI-related activities. Using the estimated value of trade activity cuts the circular link between trade and FDI-related activities, so that the estimated coefficients demonstrate the pure impact of trade activities on FDI-related activities. To apply the instrumental variable method, however, at least one exogenous factor that relates only to trade activities and not to FDI-related activities should be included in the model. One potential variable is a level of tariffs or of nontariff trade barriers. One may question whether trade barriers are really exogenous, because a firm may decide to establish a facility in a country in order to get around high trade barriers there. However, even if this is the case, the impact of trade barriers on FDI-related activities is not direct but indirect through trade activities. Therefore, trade barriers can be considered exogenous from a theoretical point of view.

To measure the level of trade barriers, we use a weighted mean and standard deviation of tariff rates across all industries. Including more detailed tariff data, such as those at the three-digit Standard Industrial Classification level, would not add explanatory power, because FDI-related data at the same industrial level are not available. Instead, the standard deviation of the tariff rate is added to capture the variety of tariff rates across different goods.

To test whether trade activities are indeed endogenous, the Hauseman test is applied. The motivation for the test is that if the variable is not endogenous, coefficients from ordinary least-squares (OLS) or 2SLS regressions should differ only by sampling error. The original form of the Hauseman test is cumbersome to derive. Instead, Hauseman (1978) suggested using the following simple form. Instead of testing the coefficients from OLS and 2SLS, the simple test examines the error term from the first-stage regression.

Let us denote the dependent variable as y_1 and the potentially endogenous explanatory variable as y_2:

$$y_1 = z_1\beta_1 + \alpha_1 y_2 + u_1 \tag{8a}$$

$$E(z'u_1) = 0. \tag{8b}$$

Equation (8b) expresses all explanatory variables other than y_2 as exogenous. If y_2 is endogenous, y_1 is one of the explanatory variables. To test for this endogeneity, we first regress y_2 on all explanatory variables except y_1:

$$y_2 = z\pi_2 + v_2 \tag{9a}$$

$$E(z'v_2) = 0 \tag{9b}$$

If y_2 is endogenous, the error term from equation (8a), μ, and the error term from equation (9a), $v_{2,}$ are correlated. Plugging equation (9a) into equation (8a), we get

$$y_1 = z_1\beta_1 + \alpha_1 y_2 + \rho_1 v_2 + e_1. \tag{10}$$

Note that e_1 is uncorrelated with $z_{1,}$ $y_{2,}$ and $v_{2.}$ Since v_2 is unobservable, we can use the estimated error term from equation (9a) to test the null hypothesis: $\rho_1 = 0$ using the equation (10). The usual OLS t-statistic is a valid test. Our result shows that both export and import activities are endogenous at the 1 percent level of confidence; therefore we choose to use 2SLS.

Table B.1 shows the results of our 2SLS regression. The positive and significant coefficient indicates that exports and FDI-related activities are complements. However, imports and FDI-related activities are not signif-

Table B.1 FDI-related activities and trade (coefficient)

	All countries	Income category of host country: Low	Middle	High
Per capita GDP	0.99	0.21	−0.41*	−0.38**
Population	0.59	−5.02**	−0.39**	0.31**
Distance	0.93*	20.75**	0.41	0.13
Export	4.67*	1.30*	1.59**	1.59**
Import	−2.97	0.79*	0.33	−0.39**
Constant	−25.88**	−172.70**	−4.00	−0.66
Number of observations	509	38	250	221
Adjusted R-squared	—	0.70	0.30	0.85

Notes: Coefficients are estimated using the Two Stage Least Square regression.
All variable are in logs.

* = indicates that the coefficients are significant at the 90 percent level of confidence.

** = indicates that the coefficients are significant at the 95 percent level of confidence.

Source: Author's calculation.

icantly related. Overall, the result implies that FDI-related activities complement, not substitute for, domestic production.

Next we grouped the sample countries by income level using the World Bank's income thresholds. (See table 4.4 for a list of these countries by income level.) Using the 1995 list of countries, our sample consists of 3 low-income countries, 20 middle-income countries, and 19 high-income countries. Table B.1 also shows the results of the 2SLS regression by income level. The results confirm that US exports and US direct investment abroad are net complements in each income category. For middle- and low-income countries, there is no statistically significant relationship (again) between US direct investment abroad and US imports. Importantly, this suggests that US direct investment in these countries does not act mainly to transfer US production abroad in order to service the US market from export platforms. However, US imports and US direct investment abroad now appear as net *substitutes* in the high-income countries. This result suggests that, as US direct investment to these countries rises, US imports from them actually decline. We know of no theoretical reason why this should happen, and the result probably is best interpreted as spurious correlation. Thus, again, the conclusion would be that US direct investment has no significant effect on US imports.