

CHAPTER 4

THEORETICAL FRAMEWORK AND METHODOLOGY

4.1 Theoretical Framework of FDI and economic growth

We consider an economy where technical progress is the result of “capital deepening” in the form of an increase in the number of varieties of capital goods available, as in Romer (1990), Grossman and Helpman (1991) and Barro and Sala-i-Martin (1994).

¹ The economy produces a single consumption good according to the following technology:

$$Y_t = AH_t^\alpha K_t^{1-\alpha} \quad (4.1)$$

where A represents the exogenous state of technology, H denotes human capital, and K stands for physical capital². We assume that human capital³ H is a given endowment. Physical capital consists of an aggregate of different varieties of capital goods, and hence capital accumulation takes place through the expansion of the number of varieties.

¹ Follow closely the specification of Barro and Sala-i-Martin (1994, Ch.6)

² In growth and growth model analysis, K is essentially capital asset, which is formed in the investment and accumulation processes, such as machinery, factories, etc.

³ Human capital can be regarded as the human capacity used in the production process to achieve higher economic productivity. Hence, human capital is the outcome of investment and accumulation processes and is accordingly called human capital assets. Investment in education, training and health will help to increase human capital stock.

Specifically, at each instant in time, the stock of domestic capital is given by:

$$K = \left\{ \int_0^N x(j)^{1-\alpha} dj \right\}^{\frac{1}{1-\alpha}} \quad (4.2)$$

That is, total capital is a composite of different varieties of capital goods, each one being denoted by $x(j)$ ⁴, $x(j)$ represents the j^{th} capital good and N is the number of capital goods in the economy.

To focus on effect of FDI on growth, this section assumes that the stock of human capital is given, while the stock of physical capital is equal to total values of capital goods produced in the economy. We also assume that the total number of varieties of capital goods, N , is produced by two types of firms: domestic and foreign firms present in the economy. The domestic firms produce n varieties out of the total number N , and the foreign firms produce n^* varieties such that:

$$N = n + n^* \quad (4.3)$$

We assume that specialized firms produce each variety of capital good, and rent it out to final goods producers at a rental rate $m(j)$. The demand for each variety of capital good, $x(j)$, is given by the equality between the rental rate and the marginal productivity of the capital good in the production of the final good, that is:

$$m(j) = \partial Y(K, H) / \partial x(j) = \frac{\partial AH^\alpha \int_0^N x(j)^{1-\alpha} d(j)}{\partial x(j)} = AH^\alpha (1-\alpha)x(j)^{-\alpha} \quad (4.4)$$

For developing countries, the shortest way to produce a new type of capital goods is to apply modern technology, which is transferred via FDI from foreign and particularly multinational corporations. An expansion in the number of capital goods requires the adaptation of technology available in more advanced countries that permits the introduction of a new type of capital goods. We assume that this process of technology adaptation is costly, requiring a fixed setup cost F before production of the new type of capital can take place.

⁴ This formulation is due to Ethier (1982).

We assume that the fixed setup cost is inversely proportional to the number of capital goods produced by foreign firms operating in the host economy. This assumption is made to capture the notion that foreign firms bring to the developing economy an advance in “knowledge” applicable to the production of new capital goods that may be already available in other countries. The above argument also implies that, for a poor country, production of existing capital goods⁵ is cheaper than that of a capital good which is entirely new to the world market. Thus, foreign direct investment is the main channel of technological progress in this framework, by making it easier to adopt the technology of producing new capital varieties.

In addition, there is a “catch-up” effect⁶ in technological progress, by which the setup cost depends negatively on how many varieties are produced domestically compared to those produced in more advanced countries (which we denote by N^*). That is, such costs will be higher in those countries who produce fewer capital goods, or the costs to improve a capital good with more knowledge content is higher than those with less knowledge content.... Thus, we postulate the following functional form for the setup cost:

$$F = F(n^*, N/N^*), \quad \text{where } \frac{\partial F}{\partial n^*} < 0 \text{ and } \frac{\partial F}{\partial (N/N^*)} < 0 \quad (4.5)$$

⁵ It may be understood that these capital goods are old in a more advanced countries, yet are new to local countries.

⁶ The “catch-up” effect, also called the theory of convergence, states that poorer economies tend to grow at faster rates than richer economies. Therefore, all economies should in the long run converge in terms of per capita income and productivity. Developing countries have the potential to grow at a faster rate than developed countries as they can replicate production methods, technologies and institutions currently used in developed countries. This addition of capital allows them to rapidly increase productivity and incomes in order to achieve a higher growth rate than developed countries and therefore converge in the long-term.

An alternative interpretation of (4.5) can be given in terms of “quality ladders”, as in Grossman and Helpman (1991). The increase in the number of varieties could be interpreted as an improvement in the quality of existing goods. Therefore, the presence of MNEs would reduce the cost of improving the quality of existing goods, generating the same negative relationship between foreign direct investment and set up costs. Moreover, the catch-up assumption could be reinterpreted as meaning that the cost of improving an existing capital goods is smaller the lowest is its quality. That is, upgrading an old typewriter is cheaper than upgrading a personal computer.

In addition to the fixed setup cost, the owner must spend variables costs and the opportunity cost of this fund- interest rate r - in order to produce capital goods. For simplicity, we assume that average variable cost remains constant, i.e, marginal cost is equal to 1. Assuming a steady state where the interest rate r is constant, profits for the producer of a new variety of capital j are:

$$\Pi(j)_t = -F(n^*_t, N_t / N^*_t) + \int_t^\infty [m(j)x(j) - x(j)]e^{-r(s-t)} ds \quad (4.6)$$

The first term on the right hand side expression of (4.6) is the fixed costs. The second one represents the total revenue from one unit of capital good after subtracting variable costs, then discounted at the interest rate.

Maximization of equation (4.6) subject to the demand equation (4.4) generates the following equilibrium level for the production of each capital good $x(j)$:

$$x(j) = HA^{1/\alpha} (1 - \alpha)^{2/\alpha} \quad (4.7)$$

$$\mathbf{Max} \quad \Pi(j)_t = -F(n^*_t, N_t / N^*_t) + \int_t^\infty [m(j)x(j) - x(j)]e^{-r(s-t)} ds$$

$$\mathbf{Subject\ to.} \quad m(j) = A(1 - \alpha)H^\alpha x(j)^{-\alpha}$$

$$\frac{\partial \Pi(j)}{\partial x(j)} = 0$$

$$\frac{\partial \left[-F(n^*_t, N_t / N^*_t) + \int_t^\infty [A(1-\alpha)H^\alpha x(j)^{1-\alpha} - x(j)]e^{-r(s-t)} ds \right]}{\partial x(j)} = 0$$

$$\frac{\partial \left[-F(n^*_t, N_t / N^*_t) + \frac{[A(1-\alpha)H^\alpha x(j)^{1-\alpha} - x(j)]}{r} \right]}{\partial x(j)} = 0$$

$$A(1-\alpha)^2 H^\alpha x(j)^{-\alpha} = 1$$

$$x(j)^\alpha = A(1-\alpha)^2 H^\alpha$$

$$\text{Thus, } x(j) = HA^{1/\alpha} (1-\alpha)^{2/\alpha}$$

Note that $x(j)$ is independent of time, that is, at each instant the level of production of each new good is the same. Moreover, the level of production across the different varieties is also the same due to the symmetry among producers. Substituting equation (4.7) into the demand function (4.4), we obtain the following expression for the rental rate:

$$m(j) = 1/(1-\alpha), \quad (4.8)$$

which gives the rental rate as a markup over maintenance costs.

Finally, we assume that there is free entry, and hence, the rate of return r will be such that profits are equal to zero. Solving for the zero profits condition $\Pi(j)_t = 0$ we obtain:

$$r = \Psi F(n^*, N / N^*)^{-1} H, \quad (4.9)$$

Zero profit Condition: $\Pi(j)_t = 0$

$$-F(n^*_t, N_t / N^*_t) + \int_t^\infty [m(j)x(j) - x(j)]e^{-r(s-t)} ds = 0$$

$$\int_t^\infty [m(j)x(j) - x(j)]e^{-r(s-t)} ds = F(n^*_t, N_t / N^*_t)$$

$$\frac{A(1-\alpha)H^\alpha x(j)^{1-\alpha} - x(j)}{r} = F(n^*_t, N_t / N^*_t)$$

$$r = F(n^*_t, N_t / N^*_t)^{-1} A^{1/\alpha} \alpha (1-\alpha)^{(2-\alpha)/\alpha} H$$

$$r = \Psi F(n^*_t, N_t / N^*_t)^{-1} H$$

where

$$\Psi = A^{1/\alpha} \alpha (1-\alpha)^{(2-\alpha)/\alpha}$$

To close the model, we need to describe the process of capital accumulation, which is driven by savings behavior. We assume that individuals maximize the following standard inter-temporal utility function⁷:

$$U_t = \int_0^\infty \frac{c_t^{1-\sigma} - 1}{1-\sigma} e^{-\rho t} dt \quad (4.10)$$

where $\sigma, \rho > 0$; $\sigma \neq 1$

where c denotes units of consumption of the final good Y , ρ is the subjective rate of time preference, σ is the consumption elasticity of marginal utility and is a constant..

This formulation assumes that the individual's utility at time 0 is a weighted sum of all future flows of utility. The multiplier, $e^{-\rho t}$ involves the rate of time preferences, a positive value of ρ means that utility are valued less the later they are received. The flow budget constraint for the individual is:

$$\dot{k}_t = f(k_t) - c_t$$

⁷ This section presents a general theoretical model based on various reference materials. For a more specific theoretical model, using Cobb-Douglas production function, see Borensztein et al (1995)

First- Order Conditions

The present-value Hamiltonian

$$J = u(c(t))e^{-\rho t} + v[f(k_t) - c_t]$$

where the expression in brackets equals \dot{k}_t in equation (budget constraint), the variable v is the present- value shadow price of income. It represents the value of an increment of income received at time t in units of utility at time 0. The first order conditions for a maximum of U are

$$\frac{\partial J}{\partial c} = 0 \Rightarrow v = u'(c)e^{-\rho t} \quad (*)$$

$$\dot{v} = -\frac{\partial J}{\partial k} \Rightarrow \dot{v} = -vf'(k) \quad (**)$$

Equation (*) is known as the Euler equation. If we differentiate equation (*)

with respect to time and substitute for v from this equation and for \dot{v} from equation (**) we get the basic condition for choosing consumption over time

$$\frac{\partial v}{\partial t} = -vf'(k)$$

$$\frac{\partial u'(c)}{\partial t} e^{-\rho t} - \rho u'(c)e^{-\rho t} = -u'(c)e^{-\rho t} f'(k)$$

$$\frac{\partial u'(c)}{\partial t} - \rho u'(c) = -u'(c) f'(k)$$

$$\frac{\partial u'(c)}{\partial t} / u'(c) = \rho - r$$

$$\frac{u''(c)\dot{c}}{u'(c)} = \rho - r$$

$$-\frac{\sigma c^{-\sigma-1}}{c^{-\sigma}} \dot{c} = \rho - r$$

$$-\sigma c^{-1} \dot{c} = \rho - r$$

$$\text{Or } \frac{\dot{c}}{c} = \frac{1}{\sigma}(r - \rho)$$

Given a rate of return equal to r , the optimal consumption path⁸ is given by the standard condition:

$$\frac{\dot{c}_t}{c_t} = \frac{1}{\sigma}(r - \rho) \quad (4.11)$$

It is easy to verify that the rate of growth of consumption must, in steady state equilibrium, equal to the rate of growth of output, which we denote by g

Finally, substituting equation (4.9) into equation (4.11), we obtain the following expression for the rate of growth of the economy:

$$g = \frac{1}{\sigma}[\Psi F(n^*, N/N^*)^{-1} H - \rho] \quad (4.12)$$

Equation (4.12) shows that foreign direct investment, which is measured by the number of products produced by foreign firms (n^*), reduces the costs of introducing new varieties of capital goods. An application from this model is that economic growth is determined by various factors. However, the most important inference from the model is the existence of a direct relationship between FDI and economic growth. Via FDI, new capital goods are created – which increases the stock of physical capital in the economy- at lower the production costs. Consequently, economic growth is positively affected. Besides, the growth rate is also inversely proportional to the gap in technology between host and home countries of FDI flows. Furthermore, the effect of FDI on the growth rate of the economy is positively associated with the level of human capital, that is, the higher the level of human

⁸ The solution to optimization problem in endogenous growth model is discussed in further details in various materials, such as “Economic Growth” by Barro, R. and Sala-i-Martin, X. (Cambridge, MA: McGraw-Hill, 1994)

capital in the host country, the higher the effect of FDI on the growth rate of the economy. Equation (4.12) also shows that a high level of human capital, H , raises the rate of growth, g .

The impact of FDI explains why poorer countries may catch up with the richer one in terms of economic growth, and why all countries, especially the poor countries, make huge efforts to attract FDI inflows. The model (4.12) hence, provides a theoretical background to examine the effects of FDI on economic growth at a macro level.

4.2 Methodology

FDI can have both direct and indirect effects on economic growth. This research concentrates on the direct effect of FDI on economic growth, based on the analytical framework used in many works. The direct effects of FDI on growth are usually channeled via investment and can be estimated using growth model at the macro- level.

First, endogenous growth model is estimated. Second, the link between FDI and domestic investment will be examined. It aims to answer the question whether FDI substitute or complement domestic investment and thus strengthening the contribution of FDI on economic growth. To do this, the investment equation including FDI will be estimated.

4.2.1 FDI and economic growth

In order to test the impact of FDI on economic growth, we use approximate equation of above theoretical framework growth model (4.12)

$$g_t = \alpha_0 + \alpha_1 FDI_t + \alpha_2 (FDI * H)_t + \alpha_3 H_t + \varepsilon_t \quad (4.13)$$

The dependent variable g_t denotes economic growth, measured by the growth rate of real Gross Domestic Product (*GDP*) per capita; FDI_t represents foreign direct investment, measured by the ratio of implemented FDI in *GDP*; The variables H_t represents the stock of human capital, measured the effect of human capital on growth. The interaction term $(FDI * H)_t$ helps to explain the role of human capital on the contribution of FDI to economic growth. The presence of this variable is regarded as the measurement of the economy's absorptive ability of FDI, which depends on the skilled labors of an economy.

The stock of human capital in a host country is critical for absorbing foreign knowledge and an important determinant of whether potential spillovers will be realized. The application of advanced technologies embodied in FDI requires a

sufficient level of human capital in host countries. That is, the higher the level of human capital in host country, the higher the effect of FDI on the country's economic growth. The interaction term estimates the combined impact of FDI and human capital and indicates the nature of the relationship between the two. A positive coefficient for the interaction term would suggest that FDI and human capital reinforce each other in advancing economic growth.

In endogenous growth theory, human capital has been recognized as an essential determinant of economic growth. Mankiw et al. (1992), Barro and Sala-i-Martin (2004), and Benhabib and Spiegel (1994) have long stressed the importance of human capital to growth in both developed and developing countries. Benhabib and Spiegel (1994) pointed out that human capital is a factor affecting productivity growth, as suggested by endogenous growth theory. These authors used the school enrollment as a proxy for human capital.

According to Tam Bang Vu et al (2007), in calculating education as a proxy for human capital, they sum up data for enrollments in secondary schools, technical schools (vocational schools in the case of China), worker training schools, and four-year colleges. Then, they divide the data on education by population to obtain the school enrollment ratio for each country and label this variable as "human capital." Phi Lan Nguyen (2006) uses the number of university and college student per thousand persons and number of literates per thousand persons as proxies for human capital variables in his study. In this study, we use secondary school enrolment rate as a proxy for human capital and enrollment in tertiary education as another proxy for higher skilled human capital.

4.2.2 FDI and domestic investment

In order to test the impact of FDI on domestic investment, we apply the investment equation that include categories of factors affected investment: factor contribute to investment (FDI), factors hypothesized by conventional investment theory (output growth and interest rate)

Neoclassical investment theory suggests that the growth rate of output is positively related to investment because it indicates changes in aggregate demand for output that investors seek to meet. Empirical evidence is consistent with this accelerator effect and shows that high output growth is associated with high investment rates (Fielding, 1997; Fielding, 1993; Greene and Villanueva, 1991 and Wai and Wong, 1982). Neoclassical theory suggests that high interest rates raise the cost of capital, which reduces the investment rate.

Government policies affect domestic investment through various channels. Government consumption spending may crowd out domestic investment by raising interest rates, by reducing the pool of funds in the markets, and by increasing distortionary taxation on investment activities. It is also possible, however, for government spending to “crowd in” domestic investment through the accelerator channel. The net effect is theoretically unpredictable; it can only be determined empirically.

The model used to test the effect of FDI as well as some other factors on domestic investment:

$$I_t = \alpha_0 + \alpha_1 FDI_t + \alpha_2 G_t + \alpha_3 R_t + \alpha_4 GC_t + \varepsilon_t \quad (4.14)$$

where G_t is the growth rate of output and R_t is the nominal interest rate. GC_t is the government consumption.

4.2.3 Nonstationary, Cointegration and Error Correction Model (ECM)

Time series econometric model is utilized to examine the relationship between the variables as suggested in the model. Prior to analyzing the long-run cointegrated time series relationships and short-run dynamics, time series variables are tested to discover the order of integration of each variable in the model.

Unit root test

In estimating time-series models, the time-series properties of the data will have an important influence on the specification of the econometric model and on the

choice of estimator. A large number of macroeconomic time-series are trended and therefore in most cases are nonstationary. The problem with nonstationary data is that the conventional OLS regression method can easily yields incorrect conclusions. Usually, the regression has a very high R^2 , t-statistics that make the estimates significant, but the results may have no economic meaning whatsoever. The reason is that the OLS estimates may be inconsistent, and thus statistical inferences are invalid. The results obtained from this kind of regression are said to be spurious and these regressions are named spurious regressions (Granger and Newbold, 1974). Testing for stationary is, therefore, crucial for analyzing time series model.

By definition, it is required that a stationary process have a constant mean and variance over time. In addition, the covariance between any two time periods is constant and time-invariant. Formally, a stochastic process x_t is said to be stationary if the following conditions are satisfied for all values of t and t-s:

$$\begin{aligned} E(x_t) &= E(x_{t-s}) = \mu \\ E[(x_t - \mu)^2] &= E[(x_{t-s} - \mu)^2] = \sigma_x^2 \quad : \quad \text{var}(x_t) = \text{var}(x_{t-s}) = \sigma_x^2 \\ E[(x_t - \mu)(x_{t-s} - \mu)] &= E[(x_{t-r} - \mu)(x_{t-r-s} - \mu)] = \gamma_s \quad : \quad \text{cov}(x_t, x_{t-s}) = \text{cov}(x_{t-r}, x_{t-r-s}) \end{aligned}$$

where μ , σ_x^2 and all γ_s are constants

Testing for nonstationarity is equivalent to testing for the existence of a unit root. Several statistical methods are constructed to test for unit roots. In this study, the familiar Augmented Dickey Fuller (ADF) method is applied.

Augmented Dickey-Fuller (ADF) Test

The Augmented Dickey-Fuller (ADF) test is an extension of the Dickey-Fuller (DF) test according to Dickey and Fuller (1979, 1981). To eliminate the possible autocorrelation occurred in the original DF test which contains only one lag, extra lagged terms of the dependent variable are included in the model, resulting in the model to be applied in the ADF test. The ADF test can be written in the three following possible forms:

$$\Delta x_t = \gamma x_{t-1} + \sum_{i=1}^p \beta_i \Delta x_{t-i} + \varepsilon_t$$

$$\Delta x_t = \alpha + \gamma x_{t-1} + \sum_{i=1}^p \beta_i \Delta x_{t-i} + \varepsilon_t$$

$$\Delta x_t = \alpha + \gamma x_{t-1} + \lambda t + \sum_{i=1}^p \beta_i \Delta x_{t-i} + \varepsilon_t$$

where Δ is the difference operator, α , γ , β and λ are coefficients to be estimated, x_t is the variable whose unit roots are examined, t is the time trend which is included to test for trend stationary of the variable and ε is the white noise error term. The test involves testing the null hypothesis that $\gamma = 0$ (the series is nonstationary) against the alternative hypothesis that $\gamma < 0$ (the series is stationary). The critical values for each of the three above models are tabulated in MacKinnon (1996). If the null hypothesis can be rejected, the series x_t is stationary at level or integrated of order zero, $x_t \sim I(0)$. However, if the null hypothesis cannot be rejected, x_t is nonstationary at level and is said to be integrated series. In an empirical model, the conventional OLS can be applied if all the variables are stationary. If not, further investigations are needed.

The problem of appropriate lag length rises since too few lags may result in over-rejecting the null when it is true, while too many lags may reduce the power of the test. In other words, the value of p should be relatively small so as to save degrees of freedom but large enough to capture the existence of autocorrelation in the error term.

An accepted solution to determine the appropriate lag length is the Akaike Information Criterion (AIC)

$$AIC = \left[\frac{ESS}{T} \right] e^{(2p/T)}$$

where ESS = residual sum of squares
 T = number of observation
 p = appropriate lag length(s)

The optimal lag length is chosen in order to minimize the AIC value. The basic idea of choosing p involves using a model selection procedure that test, whether an additional lag is significant in increasing the value of \bar{R}^2 .

Cointegration Test

To examine the long-run equilibrium relationship between variables, the Johansen and Juselius (1991, 1995) multivariate cointegration approach, which is based on estimating an error correction formulation of a VAR model is employed. To be more explicit, let a p -dimensional vector autoregression (VAR) of order k be specified as follows:

$$Y_t = \alpha_0 + \Pi_1 Y_{t-1} + \dots + \Pi_k Y_{t-k} + \mu_t$$

where Y_t is an $nx1$ vector of I(1) variables

α_0 is an $nx1$ constant vector

Π_i is an nxn matrix of unknown parameters to be estimated, $i=1,2,3,..k$

μ_t is an $nx1$ independent and identically distributed $nx1$ vector of the error terms

Using Δ as $(1-L)$, where L is called the lags operator, the system of above can be reparameterized in the error correction form as:

$$\Delta Y_t = \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \Pi Y_{t-k} + \mu_t \quad (4.15)$$

where ΔY_t is a stationary, I(0), vector.

$$\Gamma_i = \sum_{i=1}^{k-1} \Pi_i - I$$

$i = 1,2,\dots,k-1$ and

$$\Pi = \sum_{j=1}^k \Pi_j - I$$

The equation (4.15) is known as a Vector Error Correction (VEC) model. All long-run information about the relationship between variables is contained in the impact matrix Π . When the matrix Π has full column rank, it implies that all variables in Y_t are stationary. When the matrix Π has zero rank, the system is a traditional first-difference VAR involving no long-run elements. However, when the rank of Π is intermediate or $0 < \text{rank}(\Pi) = r < p$, there exist r cointegrating vectors that make the linear combinations of Y_t become stationary or cointegrated. In this case, Π can be written as the product of two $(n \times r)$ matrices, Ω and Φ , each of rank r , such that $\Pi = \Phi\Omega'$, where Ω contains the r cointegrating vectors and Φ represents the error-correction parameters. So, the difficult task for Johansen procedure is to determine the rank of Π . Johansen and Juselius (1990) proposed the cointegration rank test using the reduced rank regression. They suggest two types of the tests for r which are trace test and maximum eigenvalue test.

For conducting the trace test the null hypothesis that there are at most r cointegrating vectors is tested against the alternative hypothesis that there exists r or more cointegrating vectors. The likelihood ratio statistics for the trace test is

$$\lambda_{trace} = -T \sum_{i=r+1}^k \log(1 - \lambda_i)$$

Another test is the maximum eigenvalue test. This test is to evaluate the null hypothesis of r cointegrating vector against the alternative of $r+1$ cointegrating vectors. Rejection of this hypothesis suggests the existence of the maximum r cointegrating vectors. The likelihood ratio statistics for the maximum eigenvalue tests is

$$\lambda_{max} = -T \log(1 - \lambda_{r+1})$$

where T is the number of observations

Lag length selection

As discussed, the cointegration test is based on a VAR model which involves a number of lagged variables in the system. Determining the lag length of

VAR is crucial since the cointegration test is really sensitive to lag length. Too short lag length may not capture full dynamics of variables, while too long lag length reduces the degree of freedom. Generally, there is no consensus on what criterion should be placed on. Ideally, the selected lag length should also make the VECM have Gaussian error terms (i.e. standard normal error terms that do not suffer from non-normality, autocorrelation, heteroskedasticity, etc.) Therefore, diagnostic checks regarding these properties are conducted.

Diagnostic check

In performing VECM residual diagnostic check, three possible properties are tested, i.e. autocorrelation, heteroskedasticity and non-normality. The methods used in diagnostic check are

Lagrange-Multiplier (LM) test is used to test for VECM residual autocorrelation.

White Heteroskedasticity test (no cross terms) is used to test for heteroskedasticity.

Vector Error Correction (VEC) Model

An Error Correction Model (ECM) is a neat way of combining the long run, cointegrating relationship between the levels variables and the short run relationship between the first differences of the variables. It also has the advantage that all the variables in the estimated equation are stationary, hence there is no problem with spurious correlation.

A vector error correction (VEC) model is a restricted VAR designed for use with nonstationary series that are known to be cointegrated. The VEC has cointegration relations built into the specification so that it restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. The cointegration term is known as the *error correction term* since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. Consider the following equation.

$$y_t = \alpha_t + \beta x_t + z_t \quad (4.16)$$

$$z_t = y_t - (\alpha_t + \beta x_t) \quad (4.17)$$

“Granger Representation Theorem” (Engle and Granger, 1987) says that if x_t and y_t are cointegrated, we can find short-run adjustment dynamics pattern in the form of “Error-Correction Mechanisms” which can be written as follows.

$$\Delta x_t = \phi_1 z_{t-1} + \{lagged(\Delta x_t, \Delta y_t)\} + \varepsilon_{1t}$$

$$\Delta y_t = \phi_2 z_{t-1} + \{lagged(\Delta x_t, \Delta y_t)\} + \varepsilon_{2t}$$

where z_{t-1} is the error-correction (EC) term, ε_{1t} and ε_{2t} are white noise and ϕ_1, ϕ_2 are non-zero coefficients.

Intuition on ECM

$$z_t = y_t - (\alpha_t + \beta x_t) : \text{disequilibrium error}$$

wherever the system goes at time $t+1$, depends on the magnitude and sign of the disequilibrium error of the previous period t , at least.

Short-run dynamics: movements in the short run, modeled in the ECM, that guide the economy towards the long-run equilibrium

4.3 Data

This analysis is based on time series data set of Vietnam over the period 1986-2006. The main source of data is various issues of East Asian Economic Perspectives, Statistical Yearbook of Vietnam General Statistical Office (GSO), Asian Development Bank (ADB) Key Indicator 2006, 2007, International Monetary Fund (IMF) reports, United Nation (UN) data. Table 4.1 summarizes the variable measurement and data sources.

Table 4.1
Variable Definitions and Data Sources

Variable	Description and Sources
<i>g</i>	GDP per capita growth (annual %). Author's calculation from GDP per capita, measured in 1994dong. <i>Source: UNdata</i>
<i>H</i>	Secondary school enrolment rate used as a proxy for human capital. <i>Source: UNdata and GSO</i>
<i>H₁</i>	Ratio of Enrollment in tertiary education and Population used as another proxy for human capital. <i>Source: UNdata and GSO</i>
<i>FDI</i>	Share of foreign direct investment (as percent of GDP). <i>Source: calculation from the level of FDI and GDP, both measured in US\$</i>
<i>I</i>	Share of fixed investment (as percentage of GDP). <i>Source: East Asian Economic Perspectives 2007 (ICSEAD)</i>
<i>G</i>	GDP growth (annual %). <i>Source: ADB Key Indicators 2007</i>
<i>R</i>	Nominal interest rate (annual %). <i>Source: ADB Key Indicators 2007</i>
<i>GC</i>	Share of government consumption (as percent of GDP) <i>Source: ADB Key Indicators 2007</i>