Trade and growth: A survey of the endogenous growth theories

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ABSTRACT. This paper surveys the recent developments of the theory of growth particularly in the context of the interaction between international trade and growth. The endogenous growth models emphasize the beneficial effects of international trade on growth. However, some models provide evidence that in some circumstance imposition of trade barriers can increase the long run growth. The diversity of the implications of these models suggests that no simple policy recommendation should be made without a thorough understanding of the structure and key features of the economies. This study provides empirical evidence that trade has a positive impact on long run growth in Sri Lanka as predicted by the endogenous growth theory.

KEY WORDS. endogenous growth models, international trade, long-run growth, cointegration, human capital, new growth theory, developing countries, protection, trade barriers

Introduction

The failure of the traditional neo-classical growth theory to provide a satisfactory explanation for the dramatic disparities in economic performances across countries during the 1970s and 1980s has led to a general dissatisfaction with the theory. The economic performances of developing and developed countries during this period suggest that there is no automatic convergence in economic development across countries as has been predicted by the neo-classical theory. This period witnessed a decline in income per capita in most African countries, stagnation in the Latin American countries, and rapid rates of growth in the East Asian Newly Industrializing Countries (NICs). This alleged failure of traditional theory has inspired the development of a new approach to the economics of

growth and development known as the "New Growth Theory" or "Endogenous Growth Theory" following the pioneering work of (Romer,1986) and (Lucas,1988). These models can be considered as extensions and modifications of neo-classical theory that aim at providing satisfactory explanations for questions that were not answered by the neo-classical theory.

The most significant feature that distinguishes the endogenous growth models (EGMs) from the neo-classical growth models is the endogenizing of the sources of growth. In the neo-classical growth model, the processes of technological progress and population growth generate economic growth exogenously or completely independently. In EGMs growth arises endogenously from accumulation of human capital (Lucas, 1988) or product innovation by firms (Romer, 1990a).

This paper surveys the major contributions of the endogenous growth theory with special emphasis on the interaction between international trade and growth. The rest of the paper is organized as follows. The first section begins with a discussion of the basic neoclassical growth model due to Solow (1956) and the major conclusions and shortcomings that inspired the new growth theory and followed with the second section with a brief discussion of new growth theories. Section three surveys the EGMs, which examine the role of international trade in growth of economies employing different frameworks such as human capital accumulation and product innovation. Section four empirically examines the long run relationship between growth and a number of variables highlighted by the endogenous growth theory during 1960-2004 in Sri Lanka. Section five summarizes the major conclusions.

The new growth theory

There was dissatisfaction with the neo-classical model even in the 1960s as some researchers attempted to extend the neo-classical model to incorporate endogenous technological progress (Arrow, 1962; Uzawa, 1965). In Arrow

(1962), investment in physical and human capital leads to technological progress in the form of learning by doing. Uzawa (1965) considered technological progress as an output from a separate technology sector in the economy. However, compared to the new growth theories, the contribution of these models is very limited.

The endogenous growth model distinguishes itself from the neo-classical growth model by assuming increasing returns to scale in the aggregate production function and focusing on the role of externalities associated with innovation and human capital formation in determining the rate of return on capital investments. In the earlier endogenous growth models, the presence of human capital, which does not experience diminishing returns, generates the long run growth.

Another question that the neoclassical model was not successful in providing explanations for is why capital tends to flow from poor to rich countries despite the potentially high rates of return on investment in the poor countries with lower capital labor ratios. In the endogenous growth models, the introduction of human capital in the production function enables capital to accumulate without diminishing marginal returns, which eliminate the reason for capital to flow from rich to poor countries. These models emphasize the importance of human capital as being a crucial determinant in the growth process.

The endogenous growth theory also focuses on the effects of public policies on the long run growth of the economies. In the neo-classical model, government policies play no role in the growth process as it is solely determined by exogenous technological progress and population growth. Endogenous growth models stress that government policies can have effects on long-run growth. Several EGMs have analyzed how growth rates can be affected by government policies such as government spending, trade liberalization, taxes, and financial markets, not all of which have been analyzed in the traditional theory[1] (see Romer, 1986; Barro, 1990; Barro and Sala-i-Martin, 1995; Jones

and Manuelli, 1990; Rebelo,1991). Recent studies that follow this line of research use models extended to incorporate at least one of these extra variables.

Simple linear growth model

Consider the following simple linear endogenous growth model. This class of models includes Romer (1986) Lucas (1988) Rebelo (1991) and Barro (1990) among others. We take the model proposed by Lucas (1988). In this model, the Cobb-Douglas production function is given by;

$$(1) \qquad Y = AK^{\alpha}(HeL)^{1-\alpha}$$

Where A is a parameter that reflects the level of technology, Y is output, K is physical capital, H is human capital, L is labor and e is the share of working time devoted to production of Y.

In this model, individuals accumulate human capital by withdrawing from direct production and engaging in training or education[2]. Lucas distinguishes between internal effects and external effects of accumulation of human capital. The internal effect is the increase of that individual's own productivity. The external effect is the increase of the productivity of others, thus increasing overall productivity of the economy. Therefore he defines:

$$(2) \qquad A = A_0 \mathrm{H}^{\beta}$$

$$(3) \qquad \frac{\dot{H}}{H} = \lambda(1-e), \qquad (0 \le e \le 1)$$

where λ is the rate of investment in human capital. Production of human capital involves no physical capital. As H accumulates, A grows without bound and there is no restriction on the endogenously generated growth. Increase of A, which is the major source of economic growth, is determined by individuals' decisions to allocate their time between work and education.

Lucas then specifies the intertemporal utility of the consumers to be:

$$\max \int_0^{\infty} e^{-\rho t} U(C_t) dt \tag{4}$$

where

$$U(C_t) = \frac{C^{1-\sigma} - 1}{1-\sigma} \tag{5}$$

where C is consumption, $\sigma(> 0)$ is the intertemporal elasticity of substitution and $\rho(> 0)$ is the rate of time preference. Solving the maximization problem given in equation (4) subject to the appropriate budget constraint and human capital accumulation equation given in equations (2) and (3), Lucas derives the equilibrium growth rate of per capita output of the economy as:

$$g_Y = \frac{((1-\alpha+\beta)(\lambda-\rho+n))}{(\sigma(1-\alpha+\beta)-\beta))} \tag{6}$$

n is the rate of growth of population. It is clear from the equation (6) that growth is positively affected by the effectiveness of investment in human capital. In this model, growth arises endogenously through the externalities in accumulation of human capital, which induces increasing returns to scale (IRS). However, this key property of endogenous models, the absence of diminishing returns to capital (in a broad sense to include human capital) is questioned by recent models which show that IRS is neither necessary nor sufficient for endogenous growth. These recent models recognize that capital accumulation alone cannot sustain long run growth. They argue that in the long run capital accumulation would encounter diminishing returns. Therefore, continuing changes in methods of production, and types and qualities of products are necessary in order to

sustain long run growth. They emphasize the importance of advances of technology in order to escape from diminishing returns in the long run.

Technological progress is achieved by investing in R&D by profit maximizing individuals. If the advances of technology can be shared by producers in a non-rival manner it may allow escape from diminishing returns at the aggregate level. This class of models includes Romer (1990a), Grossman and Helpman (1990a; 1991a) and Rivera-Batiz and Romer (1991a; b), Coe and Helpman (1995). These models attempt to explain the origin of the technological progress and hence explain how government policies can have an influence in determining the long run growth of the economy.

These models can be divided into two groups. The first group of models concentrates on horizontal innovations: creation of new varieties of producer and consumer products. This group of models includes Romer (1990a), Rivera-Batiz and Romer (1991a; b) and Grossman and Helpman (1990a; 1991b). The second group concentrates on vertical innovations: improvement of the quality of the existing products. This group of models includes Segerstron et al. (1990) and Aghion and Howitt (1992).

Models with horizontal innovation

In models in which technological progress arises from expansion of the number of varieties of intermediate goods the production function of firm i is typically given by (see Romer, 1990a; Grossman and Helpman, 1990a; 1991b):

$$Y_i = AL_i^{1-\alpha} \sum_{j=1}^{N} (X_{ij})^{\alpha} \tag{7}$$

where Y_i is output, L_i is labor and X_i is the amount of j^{th} intermediate good employed in the production. This production function exhibits diminishing marginal productivity to each of the inputs and constant returns to scale in all inputs together.

In this model, technological change takes the form of expansion in the number of intermediate goods. Suppose that the intermediate goods can be measured in a common physical unit and all of them are employed in the same quantity, then, it is possible to redefine the production function as,

$$Y_i = AL_i^{1-\alpha} NX_i^{\alpha} = AL_i^{1-\alpha} (NX_i)^{\alpha} N^{1-\alpha} \tag{8}$$

For given N, the production function for the final output Y exhibits constant returns to scale for L_i and NX_i. For given quantities of L_i and NX_i equation (8) indicates that the final output increases with the expansion of number of intermediate goods. In this model, the spillover effects, which are crucial to the endogenous growth models, arise from the positive effect of the development of new technology on the future development of new technologies.

The expansion of the number of intermediate goods is justified by the decreasing returns in the intermediate usage in the production of final output. When the production of an intermediate reaches a certain level, it is no longer profitable to increase its production because of falling prices. At this point, the only source of profit in the intermediate sector is to invest in the creation of a new intermediate good. Therefore, technological change in the form of continuing expansion of the number of intermediate goods avoids the tendency for decreasing returns, which provides the basis for endogenous growth.

Models with vertical innovation

Segerstron et. al (1990) and Aghion and Howitt (1992) used the idea of vertical innovation. Under horizontal innovation, the creation of a new intermediate good did not make any old ones obsolete. But, under vertical innovation, the firm that develops a new product can only enjoy the monopoly of this product until the next invention as the higher quality intermediate drives out the lower quality intermediates completely. However, the creation of higher quality intermediates creates externalities by adding to the existing knowledge, which is non-rival.

Under vertical innovation, the production function given in equation (7) can be

$$Y_i = AL_i^{1-\alpha}\sum_{j=1}^{N}\left(\tilde{X}_{ij}\right)^{\alpha} \tag{9}$$

modified as:

where $\tilde{X}_{ij}$ is the amount of quality adjusted j[th] intermediate good employed in the production of final output which is given by,

$$\tilde{X}_{ij} = \sum_{k=0}^{k_j} q^k X_{ijk} \tag{10}$$

where k_j *is* the highest quality available in sector *j*, q^k is quality *k* and X_{ijk} is the amount of jth intermediate good of quality *k* used by the *i*th firm. Suppose that only the highest quality intermediate good is available for production and it is priced at P_{jk}, then the implied demand function for all final goods producers is;

$$X_{jk_j} = L\left[\frac{A\alpha(q^{k_j})^{\alpha}}{P_{jk_j}}\right]^{\frac{1}{1-\alpha}} \tag{11}$$

As the producer of the highest quality intermediate good has the monopoly of this product, the profit maximizing monopoly price;

$$P_{jk_j} = \frac{1}{\alpha} \tag{12}$$

Using these results we can rewrite the production function given in equation (9) as,

$$Y = A^{\frac{1}{1-\alpha}}\alpha^{\frac{2\alpha}{1-\alpha}}L\sum_{j=1}^{N} q^{k_j\frac{\alpha}{1-\alpha}} \tag{12}$$

where $Y = \Sigma_i Y_i$ and $L = \Sigma_i L_i$. Since L and N are constants, the growth of Y depends on the increase of the quality ladder positions k_j in the various sectors.

International trade and growth

The beneficial effect of international trade on the growth of economies has been thoroughly discussed in the development literature (see the surveys by Findlay, 1984; Smith, 1984; Frankel and Romer, 1999). However, previous research that adopted the neo-classical framework does not analyze the dynamic effects of international trade on growth, technological progress and welfare. These studies do not provide a very good framework for analyzing long-run growth. The theoretical literature on the relationship between trade and long-run growth has only now begun to build up with the development of new growth models during the late 1980s (i.e. Romer, 1986; Lucas, 1988; Grossman and Helpman, 1989).

A number of recent endogenous growth models that examine the links between foreign trade and economic growth provide evidence that trade does, indeed, increase growth (for example see Grossman and Helpman, 1990a; Romer, 1990a; Rivera-Batiz and Romer, 1991a; Dollar and Krray, 2002; Greenaway et al, 2002). Analyzing the dynamic effects of trade in terms of growth, Rivera-Batiz and Romer (1991b) emphasize that reduction in trade barriers has a positive effect on income through integration. A number of recent studies suggest that the performance of more outward oriented economies is superior to that of those countries pursuing more inward looking trade practices (Greenway and Nam, 1988; Santos and Amelia, 2005).

Opening up trade between countries that produce different goods would enable these countries to import goods that are not produced domestically. This would lead firms to use more specialized inputs and consequently increase productivity. The studies that attempted to quantify the effects of integration within the neo-classical framework suggest that the gains from integration are small. Rivera-Batiz and Romer (1991a) argue that if it is being calculated in the

context of an endogenous growth model, this might have been found to be much more important.

Another important effect of opening up trade is that it improves communication among countries and permits the flow of ideas. The transmission of ideas helps to avoid replication of research in different countries. Thus, each new innovation in a country would increase the global stock of knowledge capital (see Grossman and Helpman, 1991a: chapter 9). The general idea given in these models is that international trade eliminates the technological differences between trading countries and equalizes the long-run rates of growth regardless of the initial conditions.

Opening up trade also induces changes in sectoral output by allocating factors of production among sectors according to comparative advantage. Such allocation of resources would result in an increase in the rate of growth of the world economy. However, the magnitude of the allocation effect depends on the initial endowments or technology of the trading partners.

The various EGMs examining the role of trade in growth are principally different from each other in the underlying assumptions and the framework employed. Broadly they can be categorized according to the source of growth that is emphasized by the model such as investment in human capital (e.g. Lucas, 1988), R&D and integration (e.g. Romer, 1990a; Grossman and Helpman, 1991a). In the following sub sections, we survey the endogenous models that come under these categories.

Human capital accumulation as the engine of growth

A number of endogenous growth models that emphasize the role of trade in growth have identified human capital accumulation as the driving force behind self-sustained growth (Lucas, 1988,1993; Romer, 1990b; Barro, 1991)[3]. These models stress that the primary reason for the observed differences in labor productivity across countries is not only the variation in the levels of available technological knowledge but also the variation in the levels of human capital

embodied in individuals. Since the growth of output depends on technological innovations and the existing stock of knowledge, it is clear that there should be a positive correlation between growth rates and human capital, which embodies knowledge and skills.

In a number of growth models which are designed to analyze the effects of trade, growth is generated through accumulation of human capital (see Grossman and Helpman, 1990b; Stokey, 1991b; Saarenheimo, 1993). Human capital, which takes many forms, can be accumulated through formal education or engaging in production which is known as learning by doing or on the job training. In the model of Lucas (1988), human capital is defined as the skill level of the individual, which can contribute to their productivity. He argues that investment in human capital has spillover effects on the productivity of others, which tends to increase the rate of growth. In the next sub-section, we discuss the models in which individuals accumulate human capital through education. The growth models in which human capital accumulates through learning by doing is discussed in the following sub-section.

Human capital accumulation through education

A number of endogenous growth models show that investment in education has positive effects on long run growth. In the model of Stokey (1991b) in which individuals accumulate human capital by investing in education, the level of the human capital of an individual depends on the length of the period that person spends on education. His/her wage rate in entering the work force is determined by his/her level of human capital at the time. It is assumed that there are no skills acquired after entering the work force. So, the level of human capital is constant over the working lifetime. Investments in schooling have a positive external effect on human capital levels in the later cohorts.

In this model, Stokey (1991b), labor is used as the only input in the production of a continuum of goods of various qualities. Only high quality labor can produce high-quality products. Therefore, as aggregate human capital grows,

higher quality products enter the market driving out lower quality goods. In this setting, the consequences of entering into free trade are examined for a small economy. It is assumed that the small economy and the rest of the world have the same preferences and technology but have different initial stocks of knowledge, which do not spillover countries.

Stokey (1991b) examines how a shift from autarky to free trade alters the incentives for investment in human capital in the small economy. If the small economy is relatively advanced compared to the rest of the world, with the opening up to international trade, the opportunity cost of investing in human capital rises. If the small economy is very backward, then opening to the export market lowers the relative prices of goods produced by high skilled labor and in turn lowers the incentives to invest in human capital. In the long-run the small economy falls further behind the rest of the world in terms of human capital. Hence, Stokey (1991a) concludes that if the small economy is backward relative to the rest of the world free trade weakens the incentives for accumulation of human capital. However, this does not imply that the small economy is made worse-off by free trade as the traditional static gains from free trade may outweigh the losses from slower growth in human capital accumulation.

A similar approach can be seen in the multi-sector endogenous model of Saarenheimo (1993). He examines how opening up of trade barriers affects factor prices and thereby incentives to invest in education. He also analyses how human capital accumulation leads to changes in the structure of production. He focuses on a small open economy consisting of infinitely living individuals, and a continuum of goods produced by using labor and human capital.

In analyzing the effects of opening up trade with a foreign country on the output of the home country, the model suggests that the output under free trade is always greater than the output under autarky. It is also found that in spite of the beneficial effects on output, free trade is likely to slow down human capital accumulation of a small country, which in turn can adversely affect the production structure. It could lead the country towards low-tech intermediate

goods, which require little human capital. The specialization in these labor intensive goods, in turn, lowers the incentive to invest in education and in the long run lowers the level of human capital relative to the foreign countries.

Saarenheimo argues that despite these adverse structural effects, free trade is still beneficial to the home country. In addition to the static gains from specialization, it can also benefit from the rising relative prices of labor intensive goods due to the human capital accumulation in foreign countries. This implies that even in the absence of international spillovers, there is an indirect positive externality which works through changes in relative prices and allows the home country to enjoy the benefits of investments in human capital abroad.

Although the findings of Saarenheimo (1993) support the idea that the static effects of a shift in the trade regime from autarky to free trade are clearly beneficial, the welfare effects are ambiguous. Saarenheimo stresses the importance of subsidizing education to correct the inefficiencies in education technology. This would, in turn, improve both welfare and growth of LDC, even if the subsidy has not taken place in LDC itself. The findings of this paper are parallel to those of Grossman and Helpman (1990b) and Stokey (1991b).

Learning by doing

The notion of 'Learning by Doing' was first put forward by Arrow (1962). According to Arrow, knowledge accumulates as firms produce new goods. This knowledge freely transmits to the other sectors of the economy and then contributes to the other production activities of the economy. The new growth theorists who are concerned with how growth is affected by trade suggest that opening up to international trade allows a country to gain access to a large body of knowledge that has already accumulated in the rest of the world.

Lucas (1988) offers an example of a theoretical model in which rates of growth differ across countries due to different rates of human capital accumulation to the country's comparative advantage. In this model, individuals accumulate human capital by engaging in production, which in turn reduces the

unit labor requirement over time. Another feature in this model is that some activities generate greater learning spillovers than others. He considers two countries, each of which produces two commodities. A fixed quantity of labor available in each country allocates between productions of these two goods. As the two countries open up to international trade each country will specialize in the good for which it has a static comparative advantage. The country which specializes in the high technology good can grow faster in human capital and output as more learning occurs with the production of this good. The resulting different rates of human capital will lead to differences in international growth rates. Following these lines, Young (1991) developed a more detailed model.

Young (1991) examined the dynamic effects of international trade on the growth rates, technological progress and consumer welfare in a model in which growth is generated by learning by doing. In this model, increase in the productivity of an industry is not only a result of production activity of that industry but also the result of spillovers from learning by doing in other industries.

Young considered two economies; one (the LDC) is initially less technically advanced than the other (the DC). Each economy consists of a large number of consumers and perfectly competitive firms. A spectrum of goods is produced in each country using labor as the only factor of production. These goods are indexed and ordered according to the sophistication of the technical process used in the production. Thus, the production of higher indexed goods requires more advanced technologies.

The DC, which has higher technology, introduces higher numbered goods, which reduces the unit labor requirements in producing those goods. Therefore, under free trade, it is cheaper for the LDC to import them from the DC rather than producing them in the LDC. This forces LDC labor out of high numbered industries in which they can experience learning by doing into low-numbered industries in which it has exhausted learning by doing. Further the reduction in the unit labor requirements drive DC labor out of the low numbered

industries into high tech industries. Therefore, Young argues that under free trade, the DC experiences faster technological progress while the LDC experiences a slowing of the growth rate.

In analyzing the effects of free trade on the rate of growth of GDP, Young shows that free trade would tend to increase the rate of growth of GDP in DC and lower that of the LDC relative to autarky. It implies that trade will not raise the growth of income in all the economies. The result of this model, in the context of intertemporal welfare, is somewhat ambiguous. As trade increases the rate of growth accelerates technological progress in DC and the intertemporal welfare of DC consumers is unambiguously improved. Even though the consumers of the LDC suffer a decrease in its technological progress, they enjoy the static gains of trade that increases as DC experiences technological progress. However, the effects of trade on the intertemporal utility of LDC consumers depend on its population. The LDCs, which have a smaller population than that of the DC, are more likely to experience an increase in intertemporal welfare.

In a similar setting, Stokey (1991a) studies North-South trade in a market equilibrium model in which human capital accumulates through learning-by-doing. In this model, in any equilibrium, the higher income economies (the North) produce higher quality goods and the less developed economies (the South) produce low quality goods. As in Young (1991), the North is well endowed with human capital. Each region produces both domestic consumption goods and exports.

The level of human capital in the North increases with the production of higher quality goods and the higher quality labor reduces the labor input requirements for producing every good. With free trade, the lower prices of Northern goods due to the decreased cost of production force the South to expand imports of higher quality goods from the North rather than producing them domestically which in turn slows down learning-by-doing in the South. Therefore, Stokey (1991a) argues that free trade slows down learning-by-doing and growth in the South and speeds it up in the North. However, when the South

imitates the northern products it could adversely affect the monopoly position enjoyed by the Northern innovations. Grossman and Helpman (1990a, Chapter 11) suggest that Northern producers who are fortunate enough to escape imitation find fewer competitions and earn higher profits, which strengthens the incentive to innovate. Grossman and Helpman (1990b) show that the adverse effect of imitation on the incentive to innovate is offset by this positive effect.

Stokey (1991a), in analyzing the effects of changes in the levels of human capital on production, consumption, trade and welfare in the two regions, finds that these effects depend on the cost reduction patterns. If the increase in human capital in the North is neutral i.e., it reduces the labor input requirement equi-proportionally for all goods, the South is better off. Since the prices of exports of the North have fallen due to the cost reduction, now the South can import higher quality goods. The production of higher quality goods in the South contracts while the production of them in the North expands. The South enjoys higher levels of consumption of higher quality goods under the favorable shift in its terms of trade and welfare improves.

If the increase in human capital only reduces the labor input requirements in exports, the effects of such change are the same as for a neutral cost reduction. Consider the case of an increase in human capital that reduces labor input requirements only for those goods produced for domestic consumption. In this situation, all of the effects of an export-biased increase in productivity are reversed. The terms of trade for the South are not favorable as the prices of all the imports rise. Higher quality imports from the North decrease due to the higher prices and the South is forced to produce them domestically. Consumption of domestic goods in the South increases and the expenditure on imports falls.

However, Stokey (1991a) argues that the South too is better off under free trade. In addition to the benefits the South enjoys due to the lower domestic prices, its domestic welfare improves with the continuous shifting of production of higher quality goods from the North to the lower wage South where it can be

produced cheaply. The South is more likely to be worse off if the two countries are initially quite similar.

The EGMs also provide insights into the recent dramatic acceleration of growth in the Newly Industrialized Countries (NICs) such as South Korea, Singapore, Taiwan and Hong Kong. In these countries rapid growth in income has been associated with rapid changes in the composition of output. Further, there has been a significant increase in the exports of goods not formerly produced in these countries. The EGMs explaining the potential sources of growth suggest that opening up to international trade increases the number of specialized inputs, increasing growth rates (see Grossman and Helpman,1991a, Ch 6; Romer, 1990a; Rivera-Batiz and Romer, 1991a). Free trade also allows the diffusion of knowledge already available in industrial countries. Romer (1990a) also emphasizes the importance of ideas in increasing productivity.

The higher rates of growth that can be seen in these NICs can not be achieved only through increasing international trade unless there are higher levels of human capital. It is necessary to have a highly skilled labor force to deal with the changing technology. Therefore, we can argue that the main forces behind the success of NICs would be the interaction of rapid transfers of technology and the improved domestic absorption capacity made possible by the highly skilled labor force which reflects the higher levels of investment in education.

Protection and trade

New growth theorists have also analyzed the growth effects of protection in trade, especially on the economies of developing countries. However, the results of some studies provide evidence that trade restrictions can slow down the rate of growth (see Romer, 1990a) while some others have shown that they can speed up the growth rate (Grossman and Helpman, 1989;1990a). Rodriguez and Rodrik (2000) argue that the impact of eliminating trade barriers can be positive or negative while Deardoff (2001) argues that there are large gains from

eliminating barriers of trade. It seems to be a difficult task to draw a universally applicable conclusion.

The imposition of an import tariff on intermediate goods can adversely affect the productivity of the non-R&D sector. Protection also can negatively affect the profit of firms involved in R&D abroad by reducing their incentives to invest in R&D. The lower levels of investment in R&D would tend to lower the rate of growth of the countries, including the country which imposes the tariff (Rivera-Batiz and Romer, 1991a).

Contrary to the firm belief among many economists that protection can adversely affect the rate of growth of an economy, Grossman and Helpman (1991a, Chapter 9) show that in some circumstances imposition of trade barriers could increase the world-wide long run growth. For a developing country with limited innovation capacity, competition from abroad can adversely affect domestically generated innovations. Under such circumstances, an increase in protectionist tariffs should have a positive effect on the long-run growth of the economy. The experiences of East Asian economies that have demonstrated accelerated growth rates during the last two decades show that rational government policy interventions can play an important role in the growth process. In these countries, during the period of rapid growth, government intervened by readjusting exchange rates, increasing interest rates to generate savings, providing direct incentives for exports through subsidies and credits, etc. Further, the government guided investment by exercising control over the banking sector.

Using Romer (1990a), Rivera-Batiz and Romer (1991a) relate these apparently contradictory results of Romer (1990a) and Grossman and Helpman (1991a). They explain why trade barriers can sometimes speed up world-wide growth and sometimes slow it down. Rivera-Batiz and Romer (1991a) decompose the changes in growth into three effects: allocation effect, redundancy effect and integration effect[4]. The allocation effect would slow down or speed up the world-wide growth while the other two effects unambiguously

speed it up. The allocation effect stems from the movement of inputs of production among the sectors of the economy due to a reduction of trade restrictions. When there is a reduction in trade barriers, economies reallocate their resources towards the sectors where they have comparative advantage, which in turn leads to increase the rate of growth of output. The magnitude of the allocation effect depends on the initial differences of trading countries in terms of endowments and technologies.

The redundancy effect arises through the flows of ideas and goods as a result of the reduction in trade barriers. The free transmission of ideas avoids the replication of inventions or discoveries in different countries. When there is no redundancy in research, instead of replicating the inventions already done elsewhere, these research efforts can be engaged in developing new products, which consequently increase the worldwide growth rate.

The reduction in trade barriers also enables the economies to import goods that are not produced domestically. It should be noted here that this could take place only when the different countries produce different goods. The ability of firms to use specialized inputs increases their productivity. Therefore the reduction of trade restrictions has a positive impact on the growth rate of the less developed country through integration.

Rivera-Batiz and Romer (1991a) explain how one effect can offset the other and lead to an increase or decrease in the rate of growth depending on which of these effects is larger. To get a comprehensive picture of these offsetting forces, we first discuss Romer (1990a) in detail and then discuss how Rivera-Batiz and Romer (1991a) and the model of Romer (1990a) and analyze the effects of trade barriers on rate of growth.

Romer (1990a) shows that trade barriers would lead to a decrease in the worldwide rate of growth. In his model, long-run growth arises from the non-rivalry of technology (i.e., the characteristic of technology is that once discovered its use by one person or a firm does not prevent its use by another) and IRS in the research sector. Using the notion of non-rivalry, Romer separates

the rival component of knowledge, human capital, from the non-rival component, technology, which can grow without bound. Human capital, which is the accumulation effect of education and training, is embodied in the individual and hence rival. The externalities, which drive long-run growth, are generated through the non-rivalry of technology.

Trade, human capital and growth in Sri Lanka

In this section, we investigate whether there exists any long-run relations between growth and the variables highlighted by the endogenous growth theory as important growth determinants in the growth of the economy of Sri Lanka during 1960-2004. We use time series test procedures of cointegration, which enable us to identify the long run relations and to overcome many of the econometric problems associated with regression analysis[5]. Cointegration analysis provides a conceptual framework for identifying long-run co-movements between a set of time series variables and facilitates separating the long-run relationships from their short-run responses[6].

There are various approaches that have been developed for the efficient estimation and testing of cointegrating relationships among non-stationary economic variables[7]. Among these different approaches, in this study, we use Johansen's maximum likelihood procedure, which is based on complete VARs (Johansen, 1988; 1991; Johansen and Juselius,1990; 1992; 1994). The Johansen procedure provides test statistics for the number of cointegrating vectors that may exist, as well as estimates for each of the cointegrating vectors. Johansen

$$\Delta X_t = \sum_{j=1}^{p-1} \Gamma_j \Delta X_{t-j} + \Pi X_{t-1} + \mu + \phi W_t + \varepsilon_t \qquad t = 1,...T,\ j = 1,...p \tag{26}$$

begins his analysis from a vector autoregressive error correction model of order p of an n-vector time series X_t, $t = 1,...,T$.

where ε_t is an n-dimensional independent N(0, Σ) sequence, μ is a vector of constant terms and W_t is a vector of other deterministic variables.

Equation (26) is the basis for Johansen's (1988) and Johansen and Juselius's (1990) complete system analysis of cointegration. The matrix Π contains the information about long run relationships in the chosen data. Johansen's (1988; 1991) approach is based upon estimating the long-run matrix and determining the cointegrating rank (i.e. number of cointegrating vectors). Once the number of cointegrating vectors has been determined this procedure provides likelihood ratio tests for testing linear restrictions on the cointegrating parameters.

For our study, we estimate the following multivariate model using Johansen's Maximum Likelihood estimation procedure.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + ... + \Gamma_k \Delta X_{t-k} + \Pi X_{t-1} + \mu + \varepsilon \quad (27)$$

where $X_t = (Y_t, K_t, H_t, L_t, T)$ and Y_t is real GDP, K_t is the stock of physical capital, H_t is the stock of human capital measured as the average years of schooling, L_t is labor and T is a measure of trade. The real GDP in 1996 prices are from the Annual Report of the Central Bank of Sri Lanka 2003. The gross domestic capital formation is used as a proxy for the stock of physical capital and data is obtained from the Annual Report of the Central Bank of Sri Lanka 2003. Population is used as a proxy for labor. The average years of schooling is obtained from Barro and Lee (2000)[8]. We use four different measures of trade: exports (X), volume of trade (XM), imports of intermediate inputs (IM)[9] and terms of trade (TOT) (i. e., unit price of exports divided by unit price of imports)

In this study, we do not estimate a long run production function for Sri Lanka. Our central consideration involves the identification and estimation of any long-run relationships that exist between growth and the variables, which are recognized as important growth determinants by endogenous growth models. However, it is necessary to confirm that all the data being used are integrated of

the same order before estimating cointegrating relationships. The formal tests for the order of integration are carried out using the Dickey Fuller (DF) and Augmented Dickey Fuller (ADF) test procedures (see Fuller (1976) and Dickey and Fuller (1979). The results confirm that all the variables in levels are well represented by I (1) and their first differences are integrated of order zero I (0).

Table 1: DF and ADF tests of order of integration

Variable	Levels		First Difference	
	DF	ADF(2)	DF	ADF(2)
Log(GDP)	-2.69	-2.42	-3.85*	-3.58*
Log(K)	-3.17	-3.01	-7.16	-5.67
Log(H)	-3.27	-3.12	-3.93	-3.70
Log(L)	-1.67	-1.03	-5.94	-5.21
Log(X)	-2.45	-1.46	-6.86	-6.12
Log(XM)	-2.94	-1.78	-6.88	-6.52
Log(IM)	-3.01	-2.82	-7.81	-7.11

The null hypothesis is non-stationarity. The critical values at the 95 percent confidence level for the DF and ADF(2) tests with trend are -3.55 and -3.56 respectively.

The choice of the maximum lag length (k) in the VAR has been found to be reasonably robust to the determination of the dimension of the cointegrating space. Boswijk and Frances (1992) suggest that lag length of too high an order implies a loss of power while too low an order leads to potential spurious regression.

Following Boswijk and Frances (1992), we estimated the model given in equation (27) with each of the trade measures using Johansen's procedure for lag lengths k = 1, 2 and 3. Different diagnostic tests were carried out to check the possibility of serial correlation in the estimated residuals. The first test is a multivariate Ljung-Box test (see Ljung-Box, 1978) and the second and third tests

are LM type tests for first and fourth order autocorrelation (see Godfrey, 1988). For each of the models with different trade measures, the optimal lag length was chosen as follows. First, the models that their estimated residuals do not suffer from serial correlation were chosen and Schwarz (1978) model selection criteria (SC) were computed for each of them. Among them, the model that has the lowest SC is chosen as the most parsimonious model. Results of the two likelihood ratio tests of cointegration are presented in Table 2; in the table, r is the number of cointegrating vectors[10]. The determination of the number of

Table 2: Johansen maximum likelihood tests of cointegration

A: variables	Y, K, H, L, X Lags = 1
Null	Trace
R = 0	57.664***
R ≤ 1	22.612
R ≤ 2	4.566
R ≤ 3	0.110
B: variables	Y, K, H, L, XM Lags = 1
Null	Trace
R = 0	23.64**
R ≤ 1	12.59
R ≤ 2	7.81
R ≤ 3	0.72
C: variables	Y, K, H, L, IM Lags = 2
Null	Trace
R = 0	26.98**
R ≤ 1	13.06
R ≤ 2	9.31
R ≤ 3	0.32

***, **, and * indicate 1% , 5% and 10% significance respectively.
The significance values are taken from Table A1 in Johansen and Juselius (1990).

cointegrating vectors is based on the results of two likelihood ratio tests.

In Table 2, panel A, the trace test statistic suggests the existence of one cointegrating vector. In panel B, trace statistic indicates that the null hypothesis of no cointegrating vectors is rejected at the **5** percent level of significance. Panel C reports the trace test results for the variables Y, K, H and IM. The results suggest that there is only one cointegrating relation among these variables. The estimated cointegrating vectors of the above tests and their weights are given in Table 3. All the cointegrating vectors are normalized on Y.

Table 3: Normalized cointegrating vectors

(A)	Y	H	K	L	X
β	1.000	-0.20186	-0.06138	0.02061	-0.1016
α	-0.3272	-0.1182	-0.2492	-0.1128	-0.1773
(B)	Y	H	K	L	XM
β	1.000	-0.2402	-0.0727	0.0462	-0.0940
α	-0.2790	-0.0978	-0.3433	-0.0972	-0.3381
(C)	Y	H	K	L	IM
β	1.000	-0.1619	-0.0077	0.0758	-0.0183
α	-0.2677	-0.0933	-0.2841	-0.0933	-0.3946

*β and α denote the cointegrating parameters and their weights respectively.

Now we consider how to interpret the long-run relations given by the above cointegrating vectors. In each case, we have unique cointegrating vectors and interpreting the long-run stationary relations is straightforward.

To find out whether each of the variables in the cointegrating vectors is needed for the long-run relation and for possible model simplification we carry out long-run exclusion tests and weak exogeneity tests for each variable in the long-run relations. The hypotheses are formulated as:

H_1: $\beta_{ij} = 0$

H_2: $\alpha_{ij} = 0$

Where H_1 is a hypothesis that the ith variable of the jth cointegrating vector is not needed for the long run relation. H_2 is a hypothesis that the ith variable of the jth cointegrating vector is weakly exogenous for the long run relation. This means that the equation for the ith variable does not contain information about the long run parameters β (see Johansen, 1991) for a full discussion of this topic). If the weakly exogenous hypothesis is accepted, i.e., if $\alpha_{ij} = 0$, it is valid to condition on ΔX_{it} and reduce the system to a (p-1) system without affecting the estimates of β (see Johansen and Juselius, 1992). It was shown in Johansen and Juselius (1992) that conditioning on weakly exogenous variables can improve the stochastic properties of the model. By conditioning on a weakly exogenous variable, the rest of the system is likely to be much more well behaved. The likelihood ratio test procedures for testing the above hypotheses are described in Johansen (1991) and Johansen and Juselius (1990). The test statistics for both tests, which are asymptotically distributed as $\chi^2(r)$, are reported in Table 4.

Table 4: The likelihood ratio test statistics of long run exclusion and weak exogeneity

(A) Variables	Y	H	K	L	X
LR exclusion	10.65*	15.69*	16.38*	1.39	9.39*
weak exogeneity	11.09*	12.26*	5.55*	0.78	14.18*
(B): Variables	Y	H	K	L	XM

LR exclusion	9.97*	7.02*	10.38*	2.21	9.29*
weak exogeneity	9.80*	6.22*	16.60*	1.76	5.72*
(C): Variables	Y	H	K	L	IM
LR exclusion	16.26*	19.38*	19.45*	3.08	5.16*
weak exogeneity	6.49*	7.28*	12.91*	2.51	7.04*

* indicates 5% significance.

From the long-run exclusion test and weak exogeneity test results we can conclude that the variables considered are important for long-run relations. All of the estimated long-run relations suggest the importance of the stock of human capital, stock of physical capital and trade orientation in the long-run growth as predicted by the endogenous growth theory[11].

All the trade measures are cointegrated with GDP. In each long-run relation the estimated coefficient of the trade measure indicates the importance of trade orientation in long-run growth. When the measure of trade is excluded from the analysis the other variables are found to be not cointegrated. The stock of physical capital and the stock of human capital are significantly positively cointegrated with GDP. The insignificance of labor in the cointegrated vector may be due to the availability of surplus labor in the economy. Therefore, we can conclude that physical capital, human capital and trade are important determinants of long run growth as predicted by the endogenous growth theory.

Conclusions

In this paper we have surveyed recent theoretical developments in the endogenous growth literature, particularly in the context of the relationship between free trade and economic growth. The major contribution of the new growth models is to provide several mechanisms which can potentially explain questions such as differences in rates of growth across countries, differentials in returns to capital across countries and flows of capital from poor to rich countries, which were not answered by the traditional neo-classical model.

The endogenous growth model distinguishes itself from the traditional model by endogenizing the sources of unbounded growth. In new growth models, growth arises endogenously through investment in human capital and technology, which generates positive externalities and thus results in increasing returns in the aggregate production function.

The endogenous growth models emphasize the beneficial effects of international trade on the growth of economies. Free trade allows a country to gain access to a large body of knowledge that has already accumulated in the rest of the world. It also enables firms to use more specialized inputs by allowing them to import inputs that are not produced domestically and consequently increase productivity. Further, free trade increases the speed with which new products are introduced to the economy and the degree of domestic competition.

A number of endogenous growth models suggest that free trade is beneficial whenever it takes place among countries at similar development levels. In contrast, free trade is likely to weaken the incentives to invest in human capital of small economies, which are less technically advanced. However, these models stress that this does not imply that the small economy is made worse off by free trade as the traditional static gains from free trade may outweigh the losses from slowing down human capital accumulation. In addition, the small economy can also benefit from the rising relative prices of labor intensive goods due to the investments in human capital abroad. In spite of

the beneficial effects of free trade, some growth models have shown that in certain circumstances, protection could increase the worldwide long run growth rate. In the case of a developing country with limited innovation capacity, protectionist measures should have a positive effect on the long-run growth of the economy.

The diversity of the implications of the endogenous growth models examining the trade growth relationship suggests that no simple policy recommendation should be made without a thorough understanding of the structure and key features of the economies.

In the endogenous growth models, growth arises endogenously from human capital accumulation or innovation of new products. Therefore within the endogenous growth model, government policies play an important role in determining long-run growth. These models highlight several factors that can affect long-run growth. These factors include government spending, trade liberalization, taxes, and financial markets, not all of which have been analysed in the neo-classical theory.

Although a main contribution of endogenous growth theories is to allow analysis of the role of government policies in the process of growth, little progress has been made in analyzing these issues empirically. Therefore, more empirical work addressing these issues is needed to be done.

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Notes

1. For example, Barro (1990) analyses how an increase in tax rates can distort savings decisions and lower growth while government services financed by these taxes increase productivity and hence increase growth.
2. Lucas (1988) measures human capital as the skill level of the individuals, which contribute to their productivity.

3. In the neo-classical approach, little attention has been paid to the role played by human capital in the growth process.
4. Rivera-Batiz and Romer (1991a) focus only on the allocation and redundancy effects and concentrate on the integration effect in a companion paper Rivera-Batiz and Romer (1991b).
5. In regression analysis, we can only identify short-run relations. Further the relationship between the levels of the variables cannot be explored due to the danger of spurious regression results (see Engle and Granger, 1987) and hence a potentially considerable amount of information contained in the data cannot be used.
6. The basic idea of cointegration is that a set of nonstationary variables are said to be cointegrated, if there exists at least one linear combination of these variables that is stationary, defining their long-run relationship(s). This stationary linear combination is referred to as a cointegrating vector. Although a set of cointegrated variables move closely together in the long run, they may drift apart in the short-run. Therefore, any set of integrated variables that exhibit a deterministic long--run relationship while allowing for these variables to drift apart over the short--run, will have a cointegrated relationship among them.
7. Phillips and Loretan (1991) evaluate the relative merits of these various methods in terms of asymptotic efficiency and finite sample performance.
8. Average years of schooling are available for only for the years 1960,1965,1970,1975,1980,1985,1990,1995and 2000. Missing data are interpolated using the available data.
9. Grossman and Helpman (1991a), Rivera--Batiz and Romer (1991a) show that international trade can increase the growth rate by allowing the use of a wider range of intermediate inputs, which in turn facilitates more R&D or learning by doing activity.
10. The calculations are carried out by using the computer package CATS in RATS (Hansen and Juselius,(1995).
11. Here we do not estimate an error correction model, as we are not looking at short run dynamics and only interested in long run relations.

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